MR 80-7

An Annotated Bibliography of Seagrasses with Emphasis on Planting and Propagation Techniques

by
Daniel B. Knight, Paul L. Knutson, and Edward J. Pullen

MISCELLANEOUS REPORT NO. 80-7
SEPTEMBER 1980

Approved for public release;
distribution unlimited.

U.S. ARMY, CORPS OF ENGINEERS
COASTAL ENGINEERING
RESEARCH CENTER
Kingman Building
Fort Belvoir, Va. 22060

Limited free distribution within the United States of single copies of this publication has been made by this Center. Additional copies are available from:

National Technical Information Service
ATTN: Operations Division
5285 Port Royal Road
Springfield, Virginia 22161

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER MR 80-7	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) AN ANNOTATED BIBLIOGRAPHY OF SEAGRASSES WITH EMPHASIS ON PLANTING AND PROPAGATION TECHNIQUES		5. TYPE OF REPORT & PERIOD COVERED Miscellaneous Report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Daniel B. Knight, Paul L. Knutson, and Edward J. Pullen		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Department of the Army Coastal Engineering Research Center (CERRE-CE) Kingman Building, Fort Belvoir, Virginia 22060		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS G31632
11. CONTROLLING OFFICE NAME AND ADDRESS Department of the Army Coastal Engineering Research Center Kingman Building, Fort Belvoir, Virginia 22060		12. REPORT DATE September 1980
		13. NUMBER OF PAGES 46
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release, distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Annotated bibliography
Planting techniques
Propagation techniques
Seagrasses

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This bibliography includes abstracts on 145 historic and recently published research reports on seagrasses, with emphasis on Halodule, Ruppia, Thalassia and Zostera. The compilation of reports emphasizes planting and propagation techniques for seagrasses and important environmental parameters for successful transplanting. The bibliography is published to aid coastal engineers and scientists in planning, designing, and transplanting seagrasses to rehabilitate areas affected by coastal engineering projects and to stabilize substrates adjacent to navigation channels.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

PREFACE

This report is published to provide coastal engineers and scientists a comprehensive annotated bibliography on seagrasses with emphasis on planting and propagation techniques. The compilation of the bibliography was carried out under the coastal ecology research program of the U.S. Army Coastal Engineering Research Center (CERC).

The report was compiled by Daniel B. Knight, Paul L. Knutson, and Edward J. Pullen of the Coastal Ecology Branch, under the general supervision of R.P. Savage, Chief, Research Division.

Comments on this publication are invited.

Approved for publication in accordance with Public Law 166, 79th Congress, approved 31 July 1945, as supplemented by Public Law 172, 88th Congress, approved 7 November 1963.

TED E. BISHOP
Colonel, Corps of Engineers
Commander and Director

CONTENTS

		Page
	CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI)	5
I	INTRODUCTION	7
II	USE OF THE BIBLIOGRAPHY	7
III	ANNOTATED BIBLIOGRAPHY	7
IV	KEYWORD INDEX	44

CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	by	To obtain
inches	25.4	millimeters
	2.54	centimeters
square inches	6.452	square centimeters
cubic inches	16.39	cubic centimeters
feet	30.48	centimeters
	0.3048	meters
square feet	0.0929	square meters
cubic feet	0.0283	cubic meters
yards	0.9144	meters
square yards	0.836	square meters
cubic yards	0.7646	cubic meters
miles	1.6093	kilometers
square miles	259.0	hectares
knots	1.852	kilometers per hour
acres	0.4047	hectares
foot-pounds	1.3558	newton meters
millibars	1.0197×10^{-3}	kilograms per square centimeter
ounces	28.35	grams
pounds	453.6	grams
	0.4536	kilograms
ton, long	1.0160	metric tons
ton, short	0.9072	metric tons
degrees (angle)	0.01745	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins[1]

[1]To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use formula: $C = (5/9)\ (F - 32)$.

To obtain Kelvin (K) readings, use formula: $K = (5/9)\ (F - 32) + 273.15$.

AN ANNOTATED BIBLIOGRAPHY ON SEAGRASSES WITH EMPHASIS ON PLANTING AND PROPAGATION TECHNIQUES

by

Daniel B. Knight, Paul L. Knutson, and Edward J. Pullen

I. INTRODUCTION

Seagrasses are valuable resources to the coastal marine ecosystem, and coastal engineering activities have created impacts which adversely affect these resources. This annotated bibliography is published to assist coastal engineers and scientists in planning, designing and transplanting seagrasses to restore areas changed by coastal engineering projects, and to stabilize substrates adjacent to navigation channels. The report includes both the historic and the recent research published on transplanting seagrasses. Some of the citations were obtained from previously published literature reviews (Phillips, 1964; McRoy and Phillips, 1968; Zieman, Bridges, and McRoy, 1978; Jones and Schubel, 1978). This intensive review emphasizes the genera Halodule, Ruppia, Thalassia, and Zostera.

II. USE OF THE BIBLIOGRAPHY

Entries in the bibliography are arranged alphabetically by author or source and reference number. Most entries include the source information and a short abstract. A keyword index by reference number is also provided.

To search a given topic, refer to the keyword index and locate the term that best describes the subject. For example, if the keyword is Thalassia, then all references listed under Thalassia should be reviewed. If references on more specific topics are required, a combination of keywords may be used. For example, if information on "planting methods of Thalassia" is desired, then references which appear under both keywords (planting methods and Thalassia) need to be checked.

Since some references may be listed under only one of several closely related keywords; it is advisable to check many potential keywords to ensure complete coverage on a particular subject.

Some references were not located for review but, because of their reference to seagrass planting and propagation, were cited. Keywords for these publications were taken from their titles.

III. ANNOTATED BIBLIOGRAPHY

1. ADAMS, S.M., "The Ecology of Eelgrass, *Zostera marina* (L), Fish Communities. I. Structural Analysis," *Journal of Experimental Marine Biology and Ecology*, Vol. 22, No. 3, June 1976, pp. 269-291.

Fish populations in eelgrass (*Zostera marina*) beds in two different estuarine areas (Phillips Island and Bogue Sound) near Beaufort, North Carolina, were compared to determine aspects of their community structure. The fish communities were characterized by low diversity and high standing crops of biomass and energy, both of which showed seasonal variation. Wide temperature fluctuations related to the overall shallowness of the beds probably regulated the diversity of fishes utilizing the beds. The communities were dominated by pinfish (*Lagodon rhombiodes*), which comprised 45 and 67 percent of the fish biomass in the Phillips Island and Bogue Sound beds, respectively.

Changes in total body caloric content were probably related to developmental stages and changes in diet. Adult fish often had significantly higher weight-specific caloric contents than juvenile fish. Monthly or seasonal variations in caloric content of the organic matter of pinfish had little influence on the caloric content within the various sizes of the fish.

Correlation was significant between fish biomass, temperature, and Zostera biomass. Fish biomass was highest when temperature and grass biomass were at a maximum. In general, water depth over the beds had little effect on the standing crop of fish within the bed, but cooler waters which occurred at night had a large effect.

2. ADAMS, S.M., "The Ecology of Eelgrass *Zostera marina* (L), Fish Communities. II. Functional Analysis," *Journal of Experimental Marine Biology and Ecology*, Vol. 22, No. 3, June 1976, pp. 293-311.

Production and respiration of fish communities in two eelgrass beds in two different shallow estuarine systems (Phillips Island and Bogue Sound) near Beaufort, North Carolina, have been estimated for 1971-72. Annual production was 21.7 kilocalories per square meter in each bed. Pinfish accounted for 45 and 68 percent of the production in the Phillips Island and Bogue Sound beds, respectively. Annual community respiration was 57.9 and 69.7 kilocalories per square meter in the two beds, with pinfish accounting for 62.6 and 26.7 percent of the total in the Bogue Sound and Phillips Island beds, respectively. Estimation of the annual food energy consumed by the eelgrass fish community using the Winberg and daily ration methods gave values within 6 percent of each other.

Energy turnover was high (2.8), and the efficiency of energy dissipation low for the two eelgrass fish communities. High ecological efficiencies of 0.24 and 0.23 and the high overall efficiency of the eelgrass system (production-solar radiation) of 0.0051 and 0.0086 percent indicate that the eelgrass beds are efficient systems for converting consumed energy and solar radiation into fish biomass.

3. ADAMS, S.M., "Feeding Ecology of Eelgrass Fish Communities,"*Transactions of the American Fisheries Society*, Vol. 105, No. 4, July 1976, pp. 514-519.

The principal foods of fishes from eelgrass (*Zostera marina*) beds in shallow-water estuaries near Beaufort, North Carolina, were detritus, planktonic copepods, and epifaunal crustaceans. Foods produced within the eelgrass beds (e.g., crustaceans, gastropods, and detritus) probably accounted for about 56 percent by weight of the diet of the eelgrass fish communities.

Pinfish (*Lagodon rhombiodes*) under 35 millimeters fed primarily on planktonic copepods, thereafter detritus gradually replaced copepods. Pinfish about 70 millimeters long became more omnivorous and consumed a greater proportion of plant material and polychaete worms. Changes in feeding habits may have been responsible for significant differences in the weight-specific caloric contents observed between three size groups of pigfish and pinfish. Only one species fed in the seagrass beds at night, but biomass of all fish was twice as high at night than in the day.

The eelgrass fish communities are not food-limited because the total annual food production in the beds is greater than the total annual food consumption by the macrofauna.

4. ADDY, C.E., "Eelgrass Planting Guide," *Maryland Conservationist*, Vol. 24, 1947, pp. 16-17.

This report discusses transplanting methods, planting stock, planting areas, planting times, and planting methods for seeds.

5. ADDY, C.E., "Germination of Eelgrass Seed," *Journal of Wildlife Management*, Vol. 11, No. 3, July 1947, p. 279.

Methods of harvesting eelgrass (*Zostera marina*) seed are discussed. Fruiting stems of Zostera, with spathes containing seeds, are pulled up in August. These are placed in a box which is then anchored to the bottom of a salt creek, allowing the spathes to decompose and release the seed. Seeds can be stored during the winter between layers of sand in a box anchored to the bottom of a salt creek.

6. ANDERSON, R.R., "The Submerged Vegetation of Chincoteague Bay," *Assateague Ecological Studies*, Chesapeake Biological Laboratory Reference No. 446, Natural Resources Institute, University of Maryland, College Park, Md., 1970, pp. 106-155.

Submerged plants are important to the marine environment because of their soil binding roots and foliage which provides food and shelter for marine fauna. In the Chincoteague Bay area, *Zostera marina* (eelgrass) and *Ruppia maritima* (widgeongrass) are the dominant submerged aquatic species. A 2-year study was conducted on the distribution and primary production of these species. Recommendations are also given for future dredging operations.

7. ANDERSON, R.R., "Submerged Vascular Plants of the Chesapeake Bay and Tributaries," *Chesapeake Science*, Vol. 13, No. 4 (supp.), Dec. 1972, pp. 587-589.

This article provides a summary of the taxonomy, distribution, abundance, and biology of submerged vascular plants in the Chesapeake Bay and its tributaries.

8. ANDERSON, R.R., "Tentative Outline for Inventory of Submerged Aquatic Vascular Plants: *Ruppia maritima* (L.) (ditchgrass)," *Chesapeake Science*, Vol. 13 (supp.), Dec. 1972, pp. 172-174.

This report provides a key to the identification of *Ruppia maritima*.

9. AUSTIN, C.B., and THORHAUG, A., "The Economic Costs of Transplanting Seagrasses: Thalassia," *Proceedings of the Fourth Annual Conference on the Restoration of Coastal Vegetation in Florida*, Hillsborough Community College Environmental Study Center, Tampa, Fla., May 1977, pp. 70-75.

Costs of planting Thalassia seeds were determined for nursery and field planting operations. Planting is the most expensive field operation, at $0.31 per seed (1976 cost). Field collecting cost is $0.11 per seed, and nursery planting cost is $0.06 per seed. The planting phase accounts for two-thirds of direct costs of Thalassia bed creation.

10. BARILOTTI, D.C., and BACKMAN, T.W., "Irradiance Reduction: Effects on Standing Crops of the Eelgrass, *Zostera marina*, in a Coastal Lagoon," *Marine Biology*, Vol. 34, No. 1, Jan. 1976, pp. 33-40.

Abundance of the eelgrass (*Zostera marina*) in a coastal lagoon in southern California was found to correlate with the level of irradiance at depths greater than 0.5 meter below tidal datum. Field experiments during a 9-month study, using canopies to reduce illuminance by 63 percent, confirmed that turion density is a function of the irradiance the plants receive. By day 18 of the experiment, turion density in the shaded experimental areas had decreased. Turion densities were continually lower throughout the study period in the experimental areas. Flowering was also inhibited by shading. The biological implications are discussed with respect to seasonal changes in incident solar radiation, water transparency, and changes in water quality.

11. BAYLEY, S., et al., "Changes in Submerged Aquatic Macrophyte Populations at the Head of Chesapeake Bay, 1958-1975," *Estuaries*, Vol. 1, No. 3, Sept. 1978, pp. 171-182.

Submerged aquatic plant populations in the Susquehanna Flats of the Chesapeake Bay were monitored for 18 years. An exotic species, Eurasian water milfoil (*Myriophyllum spicatum*), increased dramatically from 1958 to 1962; dominant native species declined. After 1962, milfoil populations declined and the native rooted aquatics began to return to their former levels. In the late 1960's all species declined and by 1972 almost disappeared from the Susquehanna Flats. These fluctuations may have been related to several factors in the Chesapeake Bay, including tropical storms, turbidity, salinity, and disease. The use of the flats by waterfowl is related to the abundance and species composition of the submerged macrophytes.

12. BIEBL, R., and McROY, C.P., "Plasmatic Resistance and Rate of Respiration and Photosynthesis of *Zostera marina* at Different Salinities and Temperatures," *Marine Biology*, Vol. 8, No. 1, Jan. 1971, pp. 48-56.

Zostera marina (eelgrass) was studied at the Izembek Lagoon, Alaska Peninsula. Two morphologically different forms, tidepool and subtidal, were distinguished. Both showed a high tolerance to different salinities and temperatures. The plasmatic resistance was found in a range of distilled water up to 3.0 seawater (24 hours) and between -6° and 34° Celsius (12 hours). Within these resistance limits, photosynthesis, which has its maximum in 1.0 (normal) seawater, decreased nearly to zero in distilled water and in 2.0 seawater, and increased with the temperature in the tidepool form up to 35° Celsius, but in the subtidal form up to 30° Celsius only. At higher temperatures photosynthesis declined sharply in both forms. Respiration was minimum in distilled water at 0° Celsius, and increased with increasing salinity and temperature.

13. BOONE, C.G., and HOEPPEL, R.E., "Feasibility of Transplantation, Revegetation, and Restoration of Eelgrass in San Diego Bay, California," Report No. WES-MP-Y-76-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Miss., Feb. 1976.

Several methods of eelgrass (*Zostera marina*) transplantation, restoration, and revegetation in San Diego Bay, California, are evaluated. A literature

survey and current state-of-the-art eelgrass transplant methodologies are presented. Two transplanting methods are recommended; however, since neither of these has been tested in a large-scale field program, a preliminary pilot transplant study is also recommended. Estimated transplantation costs for each method are also presented.

14. BOURN, W.S., "Sea-Water Tolerance of *Ruppia maritima* L.," Boyce Thompson Institute for Plant Research, Yonkers, N.Y., Vol. 7, 1935, pp. 249-255.

15. BROOK, I.M., "Comparative Macrofaunal Abundance in Turtlegrasses (*Thalassia testudinum*) Communities in South Florida Characterized by a High Blade Density," *Bulletin of Marine Science,* Vol. 28, No. 1, Jan. 1978, pp. 212-217.

Five high density Thalassia communities (>3,000 blades per square meter), four in South Biscayne Bay and one at Murray Key in the Everglades National Park, Florida, were sampled by suction dredge in April 1973. Macrofaunal abundance ranged from 292 to 10,728 individuals per square meter. It is postulated that a high standing crop of seagrass may not be the primary determining factor in faunal abundance.

16. BURKHOLDER, P.R., and DOHENY, T.E., "The Biology of Eelgrass with Special Reference to Hempstead and South Oyster Bays, Nassau County, Long Island, New York," Contribution No. 3, Department of Conservation and Waterways, Hempstead (Long Island), N.Y., 1968.

This report includes a literature review of the history, biology, associated fauna, and nutritive values of eelgrass and techniques for transplanting and harvesting eelgrass in southeastern Nassau County, New York.

17. BURRELL, D.C., and SCHUBEL, J.R., "Seagrass Ecosystem Oceanography," *Seagrass Ecosystems: A Scientific Perspective*, C.P. McRoy and C. Helfferich, eds., Marcell Dekker, Inc., New York, 1977, pp. 195-232.

This is a review of some aspects of the chemical, geological, and physical oceanography of several seagrass systems.

18. CAMP, D.K., COBB, S.P., and VAN BREEDVELD, J.F., "Overgrazing of Seagrasses by a Regular Urchin, *Lytechinus variegatus*," *Bioscience*, Vol. 23, No. 1, Jan. 1973, pp. 37-38.

Destruction of offshore seagrass beds by aggregations of the urchin, *Lytechinus variegatus*, is described for a large area in Dixie County, Florida. The seagrasses affected were primarily turtlegrass (*Thalassia testudinum*), with lesser amounts of manateegrass (*Syringodium filiforme*) and shoalgrass (*Diplanthera wrightii*). Approximately 20 percent of the area was damaged by urchin overgrazing. Urchin density averaged 636 individuals per square meter.

19. CARLTON, J.M., et al., "Techniques for Coastal Restoration and Fishery Enhancement in Florida," Florida Marine Research Publication No. 15, Florida Department of Natural Resources Marine Research Laboratory, St. Petersburg, Fla., Oct. 1975.

Interim guidelines for reestablishment of coastal vegetation are outlined. Several perennial plants including sea oats and bitter panicgrass are recommended for stabilizing sand dunes; both of these species are currently

available from private nurseries. Smooth cordgrass and black needle rush are recommended for marsh planting. With appropriate care, such plants can be removed from natural stands and transplanted to a low-energy coast of gradual slope. Black, red, and white mangroves are suggested for reestablishing mangrove areas; root-balling of 3- to 5-foot-tall trees is a successful procedure. For grass bed restoration, four seagrasses may be used: turtlegrass, shoalgrass, manateegrass, and widgeongrass. Planting densities, transplanting times, and procedures for removal and care are discussed for each grass. The guidelines also describe habitat development using artificial fishing reefs and oyster reefs. Materials and location should be selected to promote maximum fisheries survival.

20. CARR, W.E.S., and ADAMS, C.A., "Food Habits of Juvenile Marine Fishes Occupying Seagrass Beds in the Estuarine Zone Near Crystal River, Florida," *Transactions of the American Fish Society*, Vol. 102, No. 3, July 1973, pp. 511-540.

A quantitative gravimetric analysis was made on the stomach contents of juveniles of 21 species of fishes from seagrass beds near Crystal River, Florida. The analysis was based on dry weights of food items and is expressed as percent of total stomach contents. An analysis of the stomach contents of small, sequentially arranged size classes enabled delineation of discrete ontogenetic changes in food habits in many of the species.

21. CHURCHILL, A.C., COK, A.E., and RINER, M.I., "Stabilization of Subtidal Sediments by the Transplantation of the Seagrass *Zostera marina*," Sea Grant Publication No. 78-15, Marine Science Research Center, State University of New York, Stony Brook, Dec. 1978.

Zostera marina has been successfully transplanted on dredge spoil, and appears to stabilize unconsolidated sediments. Researchers recommend manually transplanting miniplugs of seagrass sediment-free clusters, four to six shoots together with entangled roots and rhizomes. A total of 5,061 miniplugs were planted in an 0.06-hectare area with 80 percent survival. A twofold and threefold increase in rhizome length and shoot number, respectively, was noted during the first 4 months. The estimated cost of planting 0.41 hectare (1 acre) of seagrass is $3,370.

22. COTTAM, C., and ADDY, C.E., "Present Eelgrass Condition and Problems on the Atlantic Coast of North America," *Transactions of the North American Wildlife Conference*, Vol. 12, 1947, pp. 387-398.

Eelgrass was widespread in the brackish water bays and estuaries along the Atlantic coast. The plant disappeared in 1931 and 1932, causing great ecological upheaval, but began to recover by 1945 and 1946. Information is tabulated from more than 50 observers of the location and condition of eelgrass beds in 1946. In favorable areas, eelgrass develops by natural reproduction.

23. COWPER, S.W., "The Drift Algae Community of Seagrass Beds in Redfish Bay, Texas," *Contributions in Marine Science*, University of Texas Marine Science Institute, Austin, Vol. 21, Aug. 1978, pp. 125-132.

Large quantities of drift algae found over seagrass beds in Redfish Bay, Texas, showed net productivity and competed for light with the seagrasses.

The biomass of algae was very small compared to that of the seagrasses; however, the algae served as a resource for animals and reduced light over the seagrass beds.

24. DOWN, C., and WITHROW, R., "Vegetation and Other Parameters in the Brevard County Bar-Built Estuaries," Report No. NASA-CR-158242, Report-06-73, Brevard County Health Department, Titusville, Fla., 1973.

Low-altitude aerial photography, using specific interpretive techniques, can effectively delineate seagrass beds, oysterbeds, and other underwater features. Imagery was tested using several data analysis methods, ground truth, and biological testing. Approximately 45,000 acres of seagrass beds, 2,500 acres of oysterbeds, and 4,200 acres of dredged canals were mapped. These data represent selected sites only. Areas chosen have the highest quality water in Brevard County and are among the most highly recognized biologically productive waters in Florida.

25. DRYSDALE, F.R., and BARBOUR, M.G., "Response of the Marine Angiosperm *Phyllospadix torreyi* to Certain Environmental Variables: A Preliminary Study," *Aquatic Botany*, Vol. 1, 1975, pp. 97-106.

Leaf growth of *Phyllospadix torreyi* was noted both in the field and in laboratory culture. Field winter growth rate did not appear to depend on aspect or slope of substrate. In that part of the intertidal zone which *P. torreyi* dominates, average dry weight of leaf material was about 300 grams per square meter. It was hypothesized that the spring growth rate is greater than the measured winter rate, and that increasing daily incident light energy triggers the change. In the laboratory cultures, optimum growth occurred in full strength seawater (29,000 parts per million), under 100-lumen-per-square-foot light intensity (12-hour day), and at a water temperature of 12° to 14° Celsius. Growth declined in lower salinities, under lower light intensities, and at higher temperatures. However, the magnitude of decline indicated that tolerance ranges of *P. torreyi* for salinity, light, and temperature are relatively broad.

26. EARLE, S.A., "Benthic Plants in the Eastern Gulf of Mexico," *Proceedings of Marine Environmental Implications of Offshore Drilling in the Eastern Gulf of Mexico*, R.E. Smith, ed., State University System of Florida, Institute of Oceanography, St. Petersburg, Fla., 1974, pp. 153-156.

Benthic plants in the Gulf of Mexico have considerable influence on shore primary productivity, due to the broad, shallow Continental Shelf. Seagrasses and algae are significant biologically by providing a substrate for invertebrates, and geologically by precipitating calcium carbonate from seawater. There is little information available on the ecology, distribution, and general biology of benthic plants in the gulf.

27. EDWARDS, P., "Illustrated Guide to the Seaweeds and Seagrasses in the Vicinity of Port Aransas, Texas," *Contributions in Marine Science*, University of Texas Marine Science Institute, Austin, Vol. 15 (supp.), Sept. 1970.

This report provides a key to the identification of species of algae and seagrasses, including Thalassia, Ruppia, Diplanthera, and Halophila, along the Texas coast.

28. EDWARDS, R.R.C., "Ecology of a Coastal Lagoon Complex in Mexico," *Estuarine and Coastal Marine Science*, Vol. 6, No. 1, Jan. 1978, pp. 75-92.

Primary production, oxygen consumption of the substrate, and biomass of invertebrates and fish were measured in a Mexican coastal lagoon. Net production in the water column was sufficient for the metabolic requirements of the infauna in the wet season; production by macrophytes, e.g., *Ruppia maritima*, covered the increased input necessary for the epifauna and for deposition in the substrate. Bacterial respiration accounted for an estimated 61 percent, meiobenthos and macrobenthos for 27 percent, and inorganic uptake for 12 percent of substrate respiration on the lagoon flats. Differences in oxygen uptake by the substrate were related to differences in organic contents. Practical applications for the lagoon shrimp fishery are discussed.

29. ELEUTERIUS, L.N., "A Study of Plant Establishment on Spoil Areas in Mississippi Sound and Adjacent Waters," U.S. Army Engineer District, Mobile, 1974 (unpublished, Contract No. DACW01-72-C-0001).

Techniques were developed for transplantation of seagrasses and emergent vascular plants of both marshes and dunes on respective areas of barren sea bottom and dredge material. Anchors were developed for holding the transplants of three species of seagrass. *Halodule beaudettei* (shoalgrass) transplants had the greatest survival rate and demonstrated the most rapid rate of vegetative growth. Unsuccessful transplants were attributed to biological characteristics of the species, especially related to vegetative morphology, sediment deposition, and erosion.

Ten marsh and dune species were transplanted to random plots to determine the best species, season, method, and location for transplanting. Biological information on the species and ecological information on the dredged-material disposal areas were obtained. Hypersalinity of soil water of certain spoil areas was detrimental to transplants. *Panicum amarum* var. *amarulum* and *Panicum repens* were extremely successful; however, *Distichlis spicata, Spartina alterniflora*, and *Spartina patens* demonstrated superior performance under certain conditions.

30. ELEUTERIUS, L.N. "Submergent Vegetation for Bottom Stabilization," *Estuarine Research*, Vol. 2, Academic Press, New York, 1975, pp. 439-456.

Thalassia testudinum, Cymodocea manatorum, and *Diplanthera wrightii* were transplanted from natural stands to barren submerged spoil areas and control areas adjacent to undisturbed seagrass beds. Anchoring devices were developed to hold the transplants in place regardless of water depth. *Diplanthera wrightii* had the highest survival, and its growth rate exceeded that of *T. testudinum; C. manatorum* did not survive at all. Some characteristics of the morphology and growth rate of the grasses were compared under varying conditions of sediment deposition and erosion. In view of its distribution, growth, tolerance to sediment deposition, *D. wrightii* is the best candidate for further transplant studies. Successful transplants were established in control areas whereas no successful transplants were established on dredged material. Low temperatures and prolonged exposure to low salinity apparently affect seagrass beds and transplants adversely. Available plant nutrient levels of bottom (substrate) samples did not vary appreciably between vegetated and barren areas.

31. ELEUTERIUS, L.N., "The Seagrasses of Mississippi," *Journal of the Mississippi Academy of Science*, Vol., 22, 1977, pp. 57-79.

Biological features of the local species of seagrass, including productivity and decompositional aspects, are reviewed. New information is presented on the reproductive biology, productivity, culture, and salinity tolerance with notes on the local distribution of seagrasses. *Thalassia testudinum* (turtlegrass) has been studied in more detail than *Halodule beaudettei* (shoalgrass), *Cymodocea filiformis* (manateegrass), or *Halophila engelmanii*. Most research on *T. testudinum* has been on morphology, productivity, and decomposition. Major factors affecting the distribution are also explored.

32. ELEUTERIUS, L.N., and MILLER, G.J., "Observations on Seagrasses and Seaweeds in Mississippi Sound Since Hurricane Camille," *Journal of the Mississippi Academy of Science*, Vol. 21, 1976, pp. 58-63.

33. FERNALD, M.L., and WIEGAND, K.M., "The Genus Ruppia in Eastern North America," *Rhodora*, Vol. 16, No. 187, July 1914, pp. 119-127.

This study shows that in North America there are several clearly definable variants or a combination of variable characteristics in *Ruppia maritima*. Whether these should be regarded as different species is questionable.

34. FRY, B., and PARKER, P.L., "Animal Diet in Texas Seagrass Meadows: $\delta^{13}C$ Evidence for the Importance of Benthic Plants," *Estuarine and Coastal Marine Science*, Vol. 8, No. 6, June 1979, pp. 499-509.

More than 340 animals from Texas estuarine and offshore seagrass beds were analyzed for their stable carbon isotope ratios ($\delta^{13}C$ values). Fish and shrimp from seagrass beds had significantly more ^{13}C by an average of 3.3 to 5.1 parts per thousand than comparable animals collected offshore. One polychaete worm species, *Diopatra cuprea*, collected in seagrass meadows were as much as 8.3 parts per thousand enriched in ^{13}C compared to specimens from areas where phytoplankton were the major primary producers. The differences in $\delta^{13}C$ values are attributed to differences in diet. The data support the hypothesis that seagrasses and other benthic plants in Texas bays are significant sources of nutrition for juvenile shrimp and fish.

35. FRY, B., SCALAN, R.S., and PARKER, P.L., "Stable Carbon Isotope Evidence for Two Sources of Organic Matter in Coastal Sediments: Seagrasses and Plankton," *Geochimica et Cosmochimica Acta*, Vol. 41, Pergamon Press, Inc., New York, 1977, pp. 1875-1877.

Organic carbon from sediments collected in Texas seagrass meadows was rich in a stable isotope of carbon (^{13}C) by an average of 6.6 parts per thousand relative to organic carbon from offshore sediments. Within the south Texas bay system, delta ^{13}C values became increasingly more typical of offshore sediments with increasing distance from seagrass meadows. This permits the use of carbon isotope data as a measure of the relative contributions of seagrasses and plankton to sedimentary organic matter.

36. FUSS, C.M., and KELLY, J.A., "Survival and Growth of Seagrasses Transplanted Under Artificial Conditions, *Bulletin of Marine Science*, Vol. 19, No. 2, Apr. 1969, pp. 351-365.

Survival and growth of turtlegrass (*Thalassia testudinum*) and shoalgrass (*Diplanthera wrightii*) transplanted in aquariums and through-flow seawater

tanks were measured. In aquariums, turtlegrass survived 7 months and shoalgrass 3.5 months. In tanks, turtlegrass lived 12 months and produced new leaves, roots, and rhizomes, but only a few shoalgrass plants survived.

37. GOERING, J.J., and PARKER, P.L., "Nitrogen Fixation by Epiphytes on Seagrasses," *Limnology and Oceanography*, Vol. 17, No. 2, Mar. 1972, pp. 320-323.

Seagrasses (*Thalassia testudinum, Cymodocea manatorum, Diplanthera wrightii,* and *Ruppia maritima*) in Redfish Bay, Texas, showed nitrogen-fixing activity as measured by the acetylene reduction technique. Evidence is presented that epiphytes and not the macrophytes are responsible for the observed fixation, which suggests nitrogen-fixing epiphytes play an important role in the nitrogen economy of seagrass communities.

38. GOOD, R.E., et al., "Analysis and Delineation of the Submerged Vegetation of Coastal New Jersey: A Case Study of Little Egg Harbor," Rutgers State University, New Brunswick, N.J., Jan. 1978.

The submerged vegetation in Little Egg Harbor estuary of New Jersey was investigated, from September 1977 to January 1978, to determine the identification and the delineation of submerged vegetation. Remote sensing was used to delimit the important submerged macrophytes. The functions these species play in the estuarine ecosystem were also described.

Field sampling revealed extensive beds of eelgrass (*Zostera marina*) and lesser amounts of widgeongrass (*Ruppia maritima*); however, significant amounts of algal species important in other New Jersey coastal bays (sea lettuce, *Ulva lactuca*; spaghetti grass, *Codium fragile*; and a red alga, *Gracilaria*) were absent. This study demonstrated that the distribution of submerged vegetation in Little Egg Harbor can be determined through remote sensing.

A survey of literature revealed that the major functions of eelgrass beds include (a) a role in grazing and detrital food chains, (b) creation of habitat for epiphytes, epifauna, finfish, and shellfish, (c) participation in nutrient cycles, and (d) stabilization of sediments. Eelgrass beds are viewed as an important contributor to the normal functioning and health of estuarine ecosystems.

39. HANLON, R., and VOSS, G., "A Guide to the Seagrasses of Florida, the Gulf of Mexico, and the Caribbean Region," University of Miami, Sea Grant Field Guide Series No. 4, July 1975.

More species of marine flowering plants are found in the Gulf of Mexico and Caribbean Sea than anywhere else in the Western Hemisphere. They include the turtlegrass (*Thalassia testudinum*), shoalgrass (*Halodule wrightii*), manateegrass (*Syringodium filiforme*), widgeongrass (*Ruppia maritima*), *Halophila baillonis*, and *Halophila engelmanni*. A seventh species, eelgrass (*Zostera marina*), is included in order to distinguish it from the native species; however, it is a temperate species occurring as far south as North Carolina with only a few records of occurrence in Florida. Eelgrass should not be confused with turtlegrass or shoalgrass, and the distinguishing characters of each are given.

40. HARRISON, P.G., "Decomposition of Macrophyte Detritus in Seawater: Effects of Grazing by Amphipods," *Oikos*, Vol. 28, No. 23, Copenhagen, Denmark, 1977, pp. 165-169.

In the laboratory, amphipods collected from detritus in shallow water grazed on eelgrass (*Zostera marina*) but did not consume leaves from which the epibionts had been removed. The action of two adult amphipods increased the rate of decomposition of Z. *marina* leaf particles by 32 percent (5° Celsius) and 35 percent (21° Celsius) in 24 days. Experiments with homogeneously ^{14}C-labeled hay as the source of detritus gave similar results. The addition of inorganic nitrogen and phosphorus also increased the rate of decomposition, but the maximum daily rate was only 1.16 percent and was attained after 28 days.

41. HARRISON, P.G., and MANN, K.H., "Chemical Changes During the Seasonal Cycle of Growth and Decay in Eelgrass (*Zostera marina*) on the Atlantic Coast of Canada," *Journal of the Fisheries Research Board of Canada*, Vol. 32, No. 5, May 1975, pp. 615-621.

Newly formed leaves of eelgrass in winter and spring contained maximum levels of total organic matter (90 percent of dry weight), soluble organic fraction (45 percent), carbon (42 percent), and nitrogen (4.8 percent). These decreased as the leaves matured, aged, and died. Soon after death, the leaf contained only 70-percent total organic matter, 28-percent soluble organic matter, 30-percent carbon, and 1.5-percent nitrogen. Intact dead leaves showed little further change. The crude protein determination overestimated true protein up to 180 percent. The carbon-to-nitrogen ratio (C:N) was an unreliable index of the nutritional value of the plant. The two growth forms were probably in response to wave action and substrate composition. Day length, not temperature, probably controls the seasonal growth cycle.

42. HARRISON, P.G., and MANN, K.H., "Detritus Formation from Eelgrass (*Zostera marina* L.): The Relative Effects of Fragmentation, Leaching, and Decay," *Limnology and Oceanography*, Vol. 20, No. 6, Nov. 1975, pp. 924-934.

In the laboratory, dead eelgrass leaves lost a maximum of 35 percent of the original (dry) weight in 100 days at 20° Celsius. Whole leaves lost 0.5 percent of their organic content per day whereas particles smaller than 1 millimeter lost 1 percent per day. Sterilization of leaves by dry heat or potassium cyanide showed that leaching accounted for 82 percent of the total loss of organic matter from predried material and 65 percent of the loss from undried material. Bacteria alone increased the nitrogen content of the detritus but only slowly degraded the leaf material. When protozoa were introduced, they grazed on the bacteria, maintained the bacterial population in an active metabolic state, and hastened the rate of decay. The C:N ratio of incubated detritus decreased from more than 20:1 to as low as 11:1, indicating an increase in its potential food value.

43. HARTOG, C.D., "A Key to the Species of Halophila (Hydrocaritaceae), with Descriptions of the American Species," *ACTA Botanica Neerlandica*, Vol. 8, Amsterdam, The Netherlands, 1959, pp. 484-489.

44. HARTOG, C.D., *Seagrasses of the World*, North Holland Publishing Co., Amsterdam, The Netherlands, 1970.

A description and species key is given for the genera Zostera, Phyllospadix, Heterozostera, Posidonia, Halodule, Cymodocea, Syringodium, Thalassodendron, Amphilobolis, Enhalus, Thalassia, and Halophila. The origin,

evolution, and geographical distribution of seagrasses are also discussed, and a key to the identification of sterile specimens is included.

45. HARTOG, C.D., "Structure, Function, and Classification in Seagrass Communities," *Seagrass Ecosystem: A Scientific Perspective*, C.P. McRoy and C. Helfferich, eds., Marcel Dekker, Inc., New York, 1977, pp. 89-121.

The seagrasses are divided into six growth forms. These growth forms are linked to differences in ecology. It is suggested that the ability of the plant to compete is linked to growth form. The complexity and functions of community structures of seagrasses are described.

46. HECK, K.L., Jr., "Comparative Species Richness, Composition, and Abundance of Invertebrates in Caribbean Seagrass (*Thalassia testudinum*) Meadows (Panama)," *Marine Biology*, Vol. 41, No. 4, 1977, pp. 335-348.

This article reports on a year-long study of epibenthic invertebrates from seagrass (*Thalassia testudinum*) meadows along the Caribbean coast of Panama and the Panama Canal Zone. Differences in species composition and abundance among sites were primarily due to the proximity of surrounding habitats. Coral reefs contained many species that utilize the seagrass meadows. Important seasonal fluctuations in both species number and abundance occurred at each of the sites. Several species of decapod crustaceans bred year round although seasonal differences occurred in the percentage of oviparous females. Overall species composition was similar to that reported in tropical and subtropical seagrass meadows elsewhere.

47. HILLSON, C.J., *Seaweeds: A Color-Coded, Illustrated Guide to Common Marine Plants of the East Coast of the United States*, Keystone Books, Pennsylvania State University Press, University Park, Pa., 1977.

This is a color-coded guide to the identification of marine plants, including turtlegrass (*Thalassia testudinum*) and eelgrass (*Zostera marina*), commonly found on the east coast of the United States. A glossary and a bibliography are also included.

48. HIRTH, H.F., KLIKOFF, L.G., and HARPER, K.T., "Sea Grasses at Khor Umaira, People's Democratic Republic of Yemen, with Reference to their Role in the Diet of the Green Turtle, *Chelonia mydas*," *Fisheries Bulletin*, Vol. 71, No. 4, Department of Commerce, National Marine Fisheries Service, Oct. 1973, pp. 1093-1097.

Studies were made on the seagrass pastures at Khor Umaira, the People's Democratic Republic of Yemen, in July 1972. The standing crop in an equally mixed pasture of *Cymodocea serrulata* and *Syringodium isoetifolium* was greater than in a pure stand of *C. serrulata*. The average caloric content of the leaves of five genera of seagrasses at Khor Umaira ranged between 4.54 and 4.66 kilocalories per gram dry weight, ash-free. These values are similar to the values reported for seagrasses in the South Pacific and in the Caribbean. The results show that the number of calories in the standing crop can be calculated from estimation of percent cover. The role of seagrasses in the management schemes of the green turtle (*Chelonia mydas*) is described.

49. HOTCHKISS, N., *Common Marsh, Underwater and Floating-Leaved Plants of the United States and Canada*, Dover Publications, Inc., New York, 1972.

This is a reprint of two circulars on field identification of marsh and water plants in North America. It describes all of the wild-flowering plants, ferns, liverworts, and Characeae which have underwater or floating-leaved

forms and, at the same time, have characteristics by which a person can tell them apart with the naked eye. Group descriptions are given for the different kinds that cannot be told apart without a hand lens or microscope or are without flowers or seeds.

50. HUMM, H.J., "Seagrasses on the Northern Gulf Coast," *Bulletin of Marine Science*, Vol. 6, No. 4, Dec. 1956, pp. 305-308.

Observations in Mississippi Sound indicate that at least five species of marine monocotyledonous plants occur in abundance along the northern gulf coast and may be virtually continuous between Florida and Aransas, Texas. An annotated list of species and a key are included.

51. HUMM, H.J., "Epiphytes of the Seagrass, *Thalassia testudinum*, in Florida," *Bulletin of Marine Science*, Vol. 14, No. 2, June 1964, pp. 306-341.

A total of 113 species of algae are reported occurring as epiphytes on the seagrass, *Thalassia testudinum*, 92 of which have been recorded from the south Florida area, 20 to 25 percent of the total algal flora. Two groups of epiphytes are recognized, the year-round species and the seasonal annuals. Among the year-round species are calcarcous Corallinaceae which contribute significantly to the sediments of seagrass beds; the seasonal annuals are a group of large plants which may become sufficiently abundant during winter and spring to shade the *T. testudinum* significantly. Each species is annotated, and a key to the species known to occur as epiphytes on *T. testudinum* in south Florida is provided. *Stictyosiphon* ssp. and *Polysiphonia harveyi* are newly reported for Florida; *Griffithsia barbata* is newly reported for the Bahamas.

52. HUMM, H.J., "Seagrasses," *Proceedings of Marine Environmental Implications of Offshore Drilling in the Eastern Gulf of Mexico*, R.E. Smith, ed., State University System of Florida, Institute of Oceanography, St. Petersburg, Fla., Mar. 1974, pp. 149-151.

Florida's gulf coast has seagrass beds that extend 10 miles or more out on the gently sloping Continental Shelf. Three species (*Thalassia testudinum, Syringodium filiforme,* and *Halodule wrightii*) make up 99 percent of the biomass of these beds. Three other species occur but in smaller quantity or a more limited distribution. Seagrasses are important primary producers, exceeding the productivity of phytoplankton in the areas they occupy, and they also provide an essential environment for many species of invertebrates and fishes.

53. JAGELS, R., "Studies of a Marine Grass, *Thalassia testudinum* I., Ultrastructure of the Osmoregulatory Leaf Cells," *American Journal of Botony*, Vol. 60, No. 10, Oct. 1973, pp. 1003-1009.

Turtlegrass (*Thalassia testudinum*) grows completely submerged and differs from intertidal and other halophytic angiosperms in that it has no specialized salt-secretory glands. Osmoregulation appears to be by the epidermal leaf cells. The ultrastructure and proposed mode of secretion are similar to that of the salt marsh monocot, *Spartina,* but differ from that found in dicots.

54. JONES, C.R., and SCHUBEL, J.R., "Distribution of Surficial Sediments and Eelgrass in New York's South Shore Bays: An Assessment from the Literature," Special Report No. 13, Reference 78-1, Marine Sciences Research Center, State University of New York, Stony Brook, 1978.

This report covers all published and unpublished information available on the distributions of surficial sediments and eelgrass (*Zostera marina*) in New York's south shore bays. Graphical and tabular summaries of sediment texture and eelgrass cover are presented.

55. KELLER, M., and HARRIS, S.W., "The Growth of Eelgrass in Relation to Tidal Depth," *Journal of Wildlife Management*, Vol. 30, No. 2, 1966, pp 280-285.

The growth of eelgrass (*Zostera marina*) in relation to tidal depth was studied at three areas of Humboldt Bay, California. Six contours of bay bottom between +1.0 and -1.5 feet in relation to mean lower low water (MLLW) datum were sampled. The upper limit of eelgrass growth was at or slightly above +1.0 foot. This isobath was exposed to air about 15 percent of the time. The percent of eelgrass coverage, mean turion length, and eelgrass biomass all increased with increases in water depth. The density per square foot and the number of leaves per turion did not vary with depth. The optimum depth for eelgrass production was about -1.0 foot. More than 90 percent of the biomass and about 60 to 70 percent of the eelgrass acreage in south Humboldt Bay occur at or below MLLW.

56. KELLY, J.A., Jr., FUSS, C.M., and HALL, J.R., "The Transplanting and Survival of Turtle Grass, *Thalassia testudinum*, in Boca Ciega Bay, Florida," *Fishery Bulletin*, Vol. 69, No. 2, Apr. 1971, pp. 273-280.

Turtlegrass was transplanted to an unvegetated, dredged canal and a hand-cleared part of a flourishing grass bed. Complete or partial success was attained in 7 of 14 planting methods used. The best method, in which short shoots (rhizomes removed) were dipped in a solution of plant hormone (naphthalene acetic acid) and attached to construction rods for transplanting, was 100 percent successful and may be suitable for general application.

57. KENWORTHY, W.J., and FONSECA, M., "Reciprocal Transplant of the Seagrass *Zostera marina* L. Effect of Substrate on Growth," *Aquaculture*, Vol. 12, No. 3, Nov. 1977, pp. 197-213.

Eelgrass (*Zostera marina*) is an important component of the temperate coastal ecosystem. The effect of different substrate types on *Z. marina* growth was studied using transplants of individual shoots and rhizomes. The new leaves formed the most reliable parameter for relative production. Transplants originating from a natural silt environment displayed best overall growth. Plants grown in a silt substrate continually afforded better growth. The quality of the sediment was also examined. Plants grown in undisturbed natural sediments were more successful than plants in sediments which were disturbed. Aspects of the physiology and ecology of *Z. marina* are discussed with reference to the substrate.

58. KOCH, S.J., ELIAS, R.W., and SMITH, B.N., "Influence of Light Intensity and Nutrients on Laboratory Culture of Seagrasses," *Contributions in Marine Science*, University of Texas Marine Science Institute, Austin, Vol. 18, Sept. 1974, pp. 221-227.

Halodule wrightii, Halophila engelmanii, Ruppia maritima, Syringodium filiforme, and *Thalassia testudinum* were cultured in filtered seawater

converted to Von Stosch algal culture medium. The culture technique eliminated much of the loss due to dieback of leaf tissue and made possible increases in fresh weight of 3 to 30 percent in a 4-week period for the five species. Optimal growth for all species was observed at light intensities of 200 to 450 foot-candles. By contrast, growth was much slower at light intensities of less than 200 and greater than 450 foot-candles.

59. LOT, A., "General Status of Research on Seagrass Ecosystems in Mexico," *Seagrass Ecosystems: A Scientific Perspective*, C.P. McRoy and C. Helfferich, eds., Marcel Dekker, Inc., New York, 1977, pp. 233-245.

This is a discussion on the reasons for the sparse data on Mexico's coast, the different coastal seagrasses (*Thalassia, Zostera, Halophila, Halodule, Syringodium*) found in the area, and the state of seagrass ecosystems research, especially in Veracruz, Mexico. Also included is an assessment of the effects of human activity on seagrass ecosystems, and suggestions of priority areas in Mexico for future seagrass research.

60. MANN, K.H., "Ecological Energetics of the Seaweed Zone in the Marine Bay on the Atlantic Coast of Canada, Part I. Zonation and Biomass of Seaweeds," *Marine Biology*, Vol. 12, No. 1, 1972, pp. 1-10.

A survey of the zonation of seaweed in St. Margaret's Bay, Nova Scotia, Canada, showed eight major zones: (1) *Fucus* and *Ascophyllum*, (2) *Chorda* with filamentous browns, (3) *Chondrus crispus*, (4) *Zostera marina*, (5) *Laminaria digitata* with *L. longicruris*, (6) *Laminaria longicruris*, (7) *L. longicruris* with *Agarum cribrosum*, and (8) *Agarum cribrosum* with *Ptilota serrata*. *Zostera marina* occurred at the same level as *C. crispus* but replaced it in sheltered water.

61. MARINE EDUCATION CENTER, "The Seagrasses and Marine Algae of Mississippi Sound," Marine Educational Leaflet No. 7, Marine Educational Center, Gulf Coast Research Laboratory, Biloxi, Miss., Nov. 1976.

This leaflet includes a general discussion and listing of the seagrasses and marine algae in Mississippi Sound.

62. MARSH, G.A., "The Zostera Epifaunal Community in the York River, Virginia," *Chesapeake Science*, Vol. 14, No. 2, June 1973, pp. 87-91.

The invertebrates on *Zostera marina* in the lower York River, Virginia, were sampled for 14 consecutive months at three different water depths within a single bed. The five most abundant noncolonial species (*Bittium varium, Paracerceis caudata, Crepidula convexa, Ampithoe longimana*, and *Erichsonella attenuata*) accounted for approximately 59 percent of the total fauna. These species dominated the epifauna. Several other species, including *Balanus impovisus, Molgula manhattensis, Polydora ligni*, and *Ercolania fuscata*, were abundant for only brief periods. An average index of affinity (58 percent) between all synchronous sample pairs indicated a generally homogeneous fauna, although several species were differentially distributed with depth. Exfoliation of Z. *marina* after June caused a decline in plant biomass, but the abundance of epifauna continued to increase in the summer and fall. Lowest total numbers and species counts occurred in February and early March. Diversity value (H') ranged from 1.92 to 3.90 bits per individual and averaged 3.04

bits per individual for all stations. High species numbers in summer were generally counteracted by relatively low equitabilities (ε), with H' showing little seasonal change. The primary sources of nutrition for the epifauna appeared to be (1) plankton and suspended particulate matter, (2) detritus and microorganisms on the plant blades, and (3) epiphytic algae.

63. MARSH, G.A., "Ecology of the Gastropod Epifauna of Eelgrass in a Virginia Estuary," *Chesapeake Science*, Vol. 17, No. 3, Sept. 1976, pp. 182-187.

Twenty-three species of gastropod mollusks, including 10 prosobranchia and 13 opisthobranchia, were collected during a 14-month period from Zostera in the lower York River, Virginia. During the period, salinities ranged from 16.0 to 22.4 parts per thousand, and temperatures ranged from 2.8° to 28.3° Celsius. Seasonal abundance, depth distribution, and notes on the life cycles and general ecology of this epifauna are reported. *Diastoma varium* and *Crepidula convexa*, the two most abundant species collected, occurred throughout the year.

64. MARSHALL, N., and LUKES, K., "Preliminary Observations on the Properties of Bottom Sediments With and Without Eelgrass, *Zostera marina*, Cover," *Proceedings of the 1969 National Shellfisheries Association*, Vol. 60, June 1970, pp. 107-111.

In mid-July sediment conditions in a bed of *Zostera marina* were compared with those of an open area on a shoal estuarine site in southern New England. *Zostera marina* was rooted out of a plot, the blades were broken off to clear another tract, and in the open area some of the sediment was raked. Sediments from the altered and control plots were compared again in mid-August. Organic carbon, percent water and gross color characteristics for successive levels through the top 13 centimeters of the sediments were analyzed. Silt-clay was measured at the sediment surface areas where Z. *marina* had higher levels of organic carbon, a higher silt-clay content, and more interstitial water than did the open areas. Sediments from contrasting areas were more alike beneath the surface. Possible interrelationships between these surface parameters are discussed. No changes attributed to the clearing or raking of plots were observed in the 1-month period.

65. MARYLAND DEPARTMENT OF NATURAL RESOURCES, "Experimental Planting of Bay Grasses," Pamphlet, Maryland Bay Grasses Oversight Committee, in Cooperation with the Maryland Department of Natural Resources, Annapolis, Md., 1978.

This pamphlet is for the citizens who wish to plant submerged grasses. It tells what, where, and how to plant in the Chesapeake Bay. A form for evaluating experimental bay grass transplanting is presented, and it is suggested that this form be used for evaluating private plantings to provide information to the Maryland Department of Natural Resources.

66. MAYER, F.L., and LOW, J.B., "The Effect of Salinity on Widgeongrass, *Ruppia maritima*," *Journal of Wildlife Management*, Vol. 34, No. 3, July 1970, pp. 658-661.

The effects of salinity on widgeongrass (*Ruppia maritima*) were studied in a greenhouse. Plant reproduction and seed germination were greatest in freshwater. Plants grown in salinities up to 12,000 parts per million produced

seeds; few seeds were produced at the highest salinities. Six-week-old plants could tolerate a salinity of 27,000 parts per million; older plants could not tolerate salinities above 21,000 parts per million.

67. McMAHAN, C.A., "Biomass and Salinity Tolerance of Shoalgrass and Manateegrass in Lower Laguna Madre, Texas," *Journal of Wildlife Management*, Vol. 32, No. 3, July 1968, pp. 501-506.

Three different shoalgrass (*Diplanthera wrightii*) stands and a manateegrass (*Syringodium filiforme*) community in lower Laguna Madre, Texas, were sampled for biomass. The standing crop of wet shoalgrass herbage and roots is estimated to be 4,656 pounds per acre. The standing crop of wet manateegrass is estimated to be 5,795 pounds per acre. Shoalgrass exhibits a seasonal abundance; manateegrass is not seasonal. Shoalgrass sprigs planted in culture vessels lived in salinities ranging from 9.0 to 52.5 parts per thousand, but died in salinities of 3.5 and 70.0 parts per thousand. Manateegrass rhizomes planted in culture vessels survived best in a salinity of 35.0 parts per thousand; those planted in a vessel containing 52.5 parts per thousand died. Shoalgrass is important to waterfowl and provides spawning and nursery grounds for fish and shrimp. Manateegrass appears to be of minimal value.

68. McMILLAN, C., "Experimental Studies on Flowering and Reproduction in Seagrasses," *Aquatic Botany*, Vol. 2, No. 2, June 1976, pp. 87-92.

Flowering and reproduction of seagrasses in laboratory cultures were compared with responses of the same clones in Redfish Bay, Texas. Under controlled conditions, *Halophila engelmanni* produced flowers continuously from January to September. Flower production in the bay was confined to the period from April to mid-June. The effects of salinity, temperature, and photoperiod were studied in the laboratory and monitored in the bay. Of these, temperature seemed to be the chief control of the flowering period of *H. engelmanni*. Under laboratory conditions, no flowering was recorded in *Thalassia testudinum, Syringodium filiforme, Ruppia maritima*, or *Halodule wrightii*, but the flowering of *H. wrightii* in the bay from May to August suggested a response to higher temperatures than indicated for *H. engelmanni*. Fruit development of *H. wrightii* in the laboratory also indicated a higher temperature response.

69. McROY, C.P., "The Distribution and Biogeography of *Zostera marina*, Eelgrass in Alaska," *Pacific Science*, Vol. 22, 1968, pp. 507-513.

Zostera marina (eelgrass) is common on the Alaska coast, from the lagoons on the north coast of the Seward Peninsula to the southern limit of Alaska and beyond. New records of *Z. marina* in Alaska are from Adak and Atka in the Aleutian Islands, Chagvan and Nanvak Bays and Nunivak Island, and Lopp and Ikpek lagoons on the Seward Peninsula. In Prince William Sound, the distribution of *Z. marina* was altered by an uplift associated with the March 1964 earthquake.

70. McROY, C.P., "Eelgrass Under Arctic Winter Ice," *Nature*, Vol. 224, No. 5221, Nov. 1969, pp. 818-819.

Eelgrass was found living under the winter sea ice in Safety Lagoon, an embayment of the Bering Sea near Nome, Alaska. A submarine television system revealed that the plants were in good vegetative condition, and in 20 to 30

centimeters of water between the sediment and the undersurface of the ice. The odor of hydrogen sulphide, and subsequent tests with an oxygen probe, showed this water to be anoxic.

71. McROY, C.P., "Standing Stocks and Other Features of Eelgrass, *Zostera marina*, Populations on the Coast of Alaska," *Journal of the Fisheries Research Board of Canada*, Vol. 27, No. 10, Oct. 1970, pp. 1811-1821.

Eelgrass populations were sampled from southeast Alaska to Bering Strait. Those in Kinzarof and Izembek lagoons on the Alaska Peninsula had the highest standing stocks (mean, 1,510 grams dry weight per square meter); populations in Calder Bay in southeast Alaska had the lowest (65 grams dry weight per square meter). Caloric content of eelgrass averaged 4,211 calories per gram in the leaves and 3,571 calories per gram in the roots and rhizomes. The concentration of chlorophyll a in eelgrass had a mean of 0.513 milligram per gram fresh weight with one exception. Population densities were high in Kinzarof and Izembek lagoons (mean, 4,576 turions per square meter) and low in other sample areas (599 turions per square meter). Flowering plants made up 3 to 4 percent of the total population. Mean leaf length varied from 13 to 48 centimeters and width from 2.4 to 5.1 millimeters. The differences in the eelgrass populations appeared to be related to local conditions rather than a large geographical gradient.

72. McROY, C.P., and GOERING, J.J., "Nutrient Transfer Between the Seagrass *Zostera marina* and its Epiphytes," *Nature*, Vol. 248, No. 5444, Mar. 1974, pp. 173-174.

The production of leaf epiphytes on *Zostera marina* may be indirectly sustained by nutrients in the sediments. The transfer of nitrogen and carbon was measured using laboratory techniques and controls. Results indicate a direct transfer of carbon and nitrogen from *Z. marina* to its epiphytes on the leaves, showing a symbolic relationship. Nutrients are likely absorbed by the root-rhizome system from the soil and distributed to all parts of the plant. Epiphytes probably absorb nutrients that are leached through leaves.

73. McROY, C.P., and HELFFERICH, C., eds., *Seagrasses Ecosystems: A Scientific Perspective*, Vol. 4, Marcel Dekker, Inc., New York, 1979.

The report provides recommendations for research and includes background notes. These constitute a framework for an interdisciplinary study on seagrass ecosystems. Subject areas considered were productivity-physiology, systematic ecology, decomposition, consumer ecology, and oceanography. It was the opinion of these scientists that the significance of the overall contribution of seagrass ecosystems to the ecology of the ocean cannot be adequately evaluated on the basis of available knowledge. The evidence emphasizes the need to document and understand the role of seagrass ecosystems before the pressures of an overpopulated world's technological expansion unwittingly destroy the seagrass meadows.

74. McROY, C.P., and PHILLIPS, R.C., "Supplementary Bibliography on Eelgrass, *Zostera marina*," Special Scientific Report, U.S. Fish and Wildlife Service, Washington, D.C., No. 114, Jan. 1968.

This bibliography lists 204 references on eelgrass to supplement an earlier list issued in 1964 (see Phillips, 1964).

75. McROY, C.P., BARSDATE, R.J., and NEBERT, M., "Phosphorus Cycling in an Eelgrass (*Zostera marina* L.) Ecosystem," *Limnology and Oceanography*, Vol. 17, No. 1, Jan. 1972, pp. 58-67.

Uptake and excretion of phosphorus by roots and leaves of eelgrass (*Zostera marina*) were dependent on the orthophosphate concentration of the medium. In a tidal pool dominated by eelgrass, the interstitial reactive phosphorus concentrations of the sediments were as high as 75 microgram atoms per liter. The plants absorbed 166 milligrams of phosphorus per square meter per day and excreted 62 milligrams of phosphorus, per square meter per day into the water. An amount equivalent to about 41 percent of the reactive phosphorus excreted, or 3 metric tons of phosphorus, per day was exported from the lagoon into the Bering Sea. These results open a new pathway to the phosphorus cycle for some estuaries.

76. McROY, C.P., GOERING, J.J., and CHANEY, B., "Nitrogen Fixation Associated with Seagrasses," *Limnology and Oceanography*, Vol. 18 No. 6, Nov. 1973, pp. 998-1002.

The nitrogen fixing of three species of seagrasses, *Thalassia testudinum* and *Syringodium filiforme* from Florida and *Zostera marina* from North Carolina and Alaska, was examined using the acetylene reduction technique. Rates of nitrogen fixation were extremely low or undetectable. The results do not support the generalization of others that this process supplies the nitrogen required for the high productivity of seagrasses.

77. McROY, C.P., et al., "Survey of Macrophyte Resources in the Coastal Waters of Alaska," Report No. R-71-6, University of Alaska, Institute of Marine Science, College, Alaska, May 1971.

This study provides (a) a quantitative assessment of natural stocks of marine macrophytes (seaweeds and seagrasses) in the coastal water of Alaska, (b) an evaluation of the commercial value of macrophytes from data on abundance and chemical composition, (c) a reference herbarium of marine macrophytes, and (d) a compilation of data from literature on the chemical composition of Alaska marine macrophytes. The effort during the first year of study was directed toward the development of quantitative survey techniques. The significance of the research is to provide the background for the development of a new industry in Alaska.

78. MENZIES, R.J., ZANEVELD, J.S., and FRATT, R.M., "Transported Turtle Grass as a Source of Organic Enrichment of Abyssal Sediments Off North Carolina," *Deep Sea Research*, Vol. 14, Pergamon Press, Ltd., Great Britain, Feb. 1967, pp. 111-112.

The finding of a considerable amount of turtlegrass at abyssal depths off North Carolina and at bathal depth off Florida suggests seagrass as a source of organic nourishment for the deep-sea floor. Turtlegrass does not grow in the Carolinas but is abundant in southern Florida, Bermuda, and the Bahamas, which indicates that the grass is distributed by the Gulf Stream rather than simple offshore transport.

79. MEYERS, S.P., et al., "Thalassiomycetes VII. Observations on Fungal Infestations of Turtle Grass, *Thalassia testudinum* Konig., " *Bulletin of Marine Science*, Vol. 15, No. 3, Sept. 1965, pp. 548-564.

Seasonal studies of fungal infestation of turtlegrass (*Thalassia testudinum*) in Biscayne Bay, Florida, revealed a wide range of foliicolous fungi

regularly associated with this marine phanerogamic plant. The fungi can be separated into three groups, based on relative abundance and frequency of isolation. The dominant group includes species of *Labyrinthula,* the ascomycete *Lindra thalassiae,* and the deuteromycetes *Hormodendron, Cephalosporium,* and *Dendryphiella arenaria.* Variabilities of infestation and differences observed between the foliicolous and lignicolous mycota of estuarine environments are discussed.

80. MONTGOMERY, J.R., et al., "Release of Cadmium, Copper, Nickel and Zinc by Sewage Sludge and the Subsequent Uptake by Members of a Turtle Grass (*Thalassia testudinum*) Ecosystem," Report No. CEER-2, Energy Research and Development Administration, Oak Ridge, Tenn., May 1977.

The rates of uptake by a turtlegrass (*Thalassia testudinum*) ecosystem of cadmium, chromium, copper, nickel, lead and zinc, which were leached from sewage sludge by seawater, were determined. The experimental design used aerated-flowing seawater which passes over a bed of sewage sludge before traversing a model ecosystem.

81. MORRILL, J.B., "The Submerged and Shoreline Vegetation of Three Canal Systems, Siesta Key, Florida--Preliminary Observations and Recommendations," *Proceedings of the First Annual Conference on Restoration of Coastal Vegetation in Florida,* Hillsborough Community College Environmental Study Center, Tampa, Fla., May 1974, p. 39.

Distribution of marine grasses, water circulation, and water quality were studied in three canal systems in 1972. Two canal systems had vegetated shorelines, the other had seawalls. The water quality was different in each of the three canal systems. Distribution of marine grasses was related to recruitment, depth and width of the canals, tidal current velocities, and presence of shoreline vegetation. Recommendations include a canal design for optimal tidal flushing, trimming of shoreline vegetation, removal of aquatic plants and debris that enter the open bays, and aeration of the bottom waters in dead-end canals.

82. NELSON, W.G., "Experimental Studies of Selective Predation on Amphipod: Consequences for Amphipod Distribution and Abundance," *Journal of Experimental Marine Biology and Ecology*, Vol. 38, No. 3, May 1979, pp. 225-245.

The relationship between the amphipods found associated with eelgrass (*Zostera marina*) and the common predators have been examined by laboratory experiments and field sampling. Laboratory experiments showed that of the most abundant potential predators on eelgrass amphipods, the pinfish (*Lagodon rhomboides*) and the grass shrimp (*Palaemonetes vulgaris*) were among the most effective predators. Selective feeding by these two species, with respect to prey species, size, and sex, was demonstrated. An examination of the field data in the light of the laboratory selection experiments suggests that the presence of pinfish may (a) determine the relative abundances of different types of amphipod species, (b) determine seasonal changes in species diversity by selectively removing certain species, and (c) determine, through an interaction with habitat complexity, the spatial distribution of amphipod abundance and diversity within eelgrass beds.

83. NELSON, W.G., "A Comparative Study of Amphipods in Seagrasses from Florida to Nova Scotia," *Bulletin of Marine Science*, Vol. 30, No. 1, Jan. 1980, pp. 80-89.

Amphipods associated with seagrass beds were studied along a latitudinal range from Florida to Nova Scotia. Samples were divided into the Acadian, Virginian, and Caribbean faunal provinces and compared with respect to mean density, number of species, diversity, and evenness of amphipods. No significant differences in these parameters among the faunal provinces were found. For samples from *Zostera marina* sites, density of amphipods decreased with increasing latitude. Samples from *Thalassia testudinum* sites had significantly lower values of density, number of species, and evenness than either *Halodule wrightii* or *Z. marina* sites. Significant differences were found between the most northern sites and the most southern sites in the size and relative abundance of epifaunal species (but not infaunal species). These differences may be due to a difference in predation intensity at the two locations.

84. ODUM, H.T., "Productivity Measurements in Texas Turtle Grass and the Effects of Dredging an Intracoastal Channel," University of Texas Marine Science Institute, Institute of Marine Science, Austin, Vol. 9, 1963, pp. 48-53.

Benthic chlorophyll a and diurnal oxygen productivity were measured in turtlegrass beds containing *Thalassia testudium* and *Diplanthera wrightii* in Redish Bay, Texas, before and after the dredging of an intracoastal canal. Moderate values of photosynthesis (2 to 8 grams of oxygen per square meter per day) were observed in the spring of 1959 following a period of shading by turbid dredge waters, but exceptionally high values (12 to 38 grams per square meter per day) were recorded the following spring in those areas not smothered with silt. Chlorophyll a in 1959 averaged 0.0338 gram per square meter but increased to 0.68 gram per square meter the following summer.

85. ODUM, H.T., "Tropical Marine Meadows," *Coastal Ecological Ecosystems of the United States*, H.T. Odum, B.J. Copeland, and E.A. McMahan, eds., Vol. 1, Conservation Foundation, Washington, D.C., June 1974, pp. 442-487.

The biology of tropical marine meadows and underwater grassy vegetation in Florida, Texas, Puerto Rico, and the Bahamas is discussed.

86. O'GOWER, A.K., and WACASEY, J.W., "Animal Communities Associated with Thalassia, Diplanthera, and Sand Beds in Biscayne Bay. I. Analysis of Communities in Relation with Water Movements," *Bulletin of Marine Science*, Vol. 17, No. 1, Mar. 1967, pp. 175-210.

Random samples collected from Diplanthera, Thalassia, and sand beds in the shallow sublittoral zones at Key Biscayne and Virginia Key, Florida, indicated both dissimilarities and similarities between the communities inhabiting these environments. The data on occurrences and densities of species in these communities were analyzed, and associations of densities and selected environmental factors were determined.

87. ORPURT, P.A., and BORRAL, L.L., "The Flowers, Fruits and Seeds of *Thalassia testudinum* Koenig," *Bulletin of Marine Science*, Vol. 14, No. 2, June 1964, pp. 296-302.

The flowers of turtlegrass (*Thalassia testudinum*) are redescribed from specimens collected in Biscayne Bay, Florida. An account is given of fruit development and structure. Anatomy of the seed and the germination of turtlegrass are described for the first time.

88. ORTH, R.J., "Benthic Infauna of Eelgrass, *Zostera marina*, Beds," *Chesapeake Science*, Vol. 14, No. 4, Dec. 1973, pp. 258-269.

The infauna of Zostera beds in the Chesapeake Bay-York River estuary and Chincoteague Bay was sampled in March and July 1970 using a corer. Sediments were fine sand or very fine sand. Sediments varied from poor to moderately well sorted and were positively correlated with the density of Zostera.

A total of 117 macroinvertebrate taxa were collected. Species number decreased both up the estuary and seasonally from March to July. Movement of epifaunal species from the sediments to the leaves in summer partly accounted for this seasonal difference. This seasonal decrease was not noted at the station farthest up the estuary where Zostera was scarce. Faunal similarity as measured by three indices, indicates that the infauna of most Zostera beds in the Chesapeake Bay area is similar, except at the upper estuary limits of Zostera.

89. ORTH, R.J., "Destruction of Eelgrass, *Zostera marina*, by the Cownose Ray, *Rhinoptera bonasus*, in the Chesapeake Bay," *Chesapeake Science*, Vol. 16, No. 3, Sept. 1975, pp. 205-208.

Destruction of Zostera beds in the York River, Virginia, is attributed to the digging activities of the cownose ray (*Rhinoptera bonasus*). The physically stable Zostera habitat with high faunal diversity and density was replaced by an unstable habitat with low faunal diversity and density.

90. ORTH, R.J., "The Role of Disturbance in an Eelgrass, *Zostera marina*, Community," Ph.D. Dissertation, University of Maryland, College Park, Md., 1975.

Eelgrass (*Zostera marina*) beds in the Chesapeake Bay, Virginia, were studied. Samples were taken in an intact eelgrass bed and within different-sized patches of eelgrass. Eelgrass areas were subjected to different levels of physical disturbance. Exposed rhizome layers as a result of physical disturbances increased habitat space and allowed a significant increase in abundance of polychaete annelid (*Polydora ligni*). A predator exclusion cage, simulating decreased disturbance, produced increased species diversity and density.

Natural disturbance occurred with the invasion of cownose rays (*Rhinoptera bonasus*) and toadfish (*Opsanus tau*). The rays removed large areas of eelgrass, resulting in much of the patchiness observed in eelgrass beds. The infaunal density and diversity were significantly reduced in an eelgrass bed destroyed by ray activity.

91. ORTH, R.J., "The Demise and Recovery of Eelgrass, *Zostera marina*, in the Chesapeake Bay, Virginia," *Aquatic Botany*, Vol. 2, No. 2, June 1976, pp. 141-159.

From 1971-74 eelgrass (*Zostera marina*) declined 36 percent. Evidence indicating the loss was determined from aerial photos and ground-truth reconnaissance. The decline is attributed to the cownose ray, human disturbance, and a rise in water temperature.

92. ORTH, R.J., "Effect of Nutrient Enrichment on Growth of the Eelgrass, *Zostera marina*, in the Chesapeake Bay, Virginia, USA," *Marine Biology*, Vol. 44, No. 2, 1977, pp. 187-194.

The addition of two commercial fertilizers had a positive effect on the growth of *Zostera marina* in the Chesapeake Bay. There was a significant increase in the length, biomass, and total number of turions in fertilized plots compared with controls. This short-term field experiment suggests that Zostera beds in the Chesapeake Bay are nutrient-limited, that the growth form of Zostera may be related to the sediment nutrient supply, and that Zostera may competitively exclude *Ruppia maritima* by the shading of the light.

93. ORTH, R.J., "The Importance of Sediment Stability in Seagrass Communities," *Ecology of Marine Benthos*, B.C. Coull, ed., University of South Carolina Press, Columbia, S.C., 1977, pp. 281-300.

Dense seagrass beds, such as Zostera in the Chesapeake Bay, stabilize sediments, promote diverse and abundant benthic fauna, and protect fauna from predation from blue crabs.

94. PATRIQUIN, D.G., "Estimation of Growth Rate, Production and Age of the Marine Angiosperm *Thalassia testudinum* Konig.," *Caribbean Journal of Science*, Vol. 13, No. 1-2, Institute of Marine Science, University of Puerto Rico, Mayaguez, June 1973, pp. 111-123.

There is a linear relation between average growth rate and the average maximum leaf length of Thalassia. The ratio production-to-standing crop (wet weight including epiphytes) tends to be constant. New foliage is developed at intervals of about 15 days. The age, growth rate, and production of underground parts can be estimated by counting leaf scars.

95. PATRIQUIN, D.G., "Migration of Blowouts in Seagrass Beds at Barbados and Carriacou West Indies and its Ecological and Geological Implications," *Aquatic Botany*, Vol. 1, Elsevier Scientific Publishing Company, Amsterdam, The Netherlands, 1975, pp. 163-189.

Blowouts are grass-free depressions within seagrass beds at Barbados and Carriacou and reported in the literature to be common elsewhere in the Caribbean region. They are typically crescent-shaped in plan view with the convex side seaward, and are characteristic of elevated seagrass beds in regions of moderate to strong wave action. The seaward edge is steep and exposes rhizomes of Thalassia; the leeward edge slopes gently upward to the seagrass plateau and is usually colonized by Syringodium. The general morphology of the blowouts, the zonation of organisms across them, and the existence at some blowouts of a lag deposit of cobble-sized material at the scarp base continuous with a rubble layer below the seagrass carpet suggest that the blowouts "migrate" seaward. Measurements of scarp erosion and of the advance

of Syringodium onto the blowout floor over a period of 1 year confirm this. It is estimated that in the region of blowouts any one point will be recurrently eroded and restabilized at intervals of 5 to 15 years. Such processes limit successional development of the seagrass beds, disrupt sedimentary structures, and may result in deposits much coarser than those characteristic of the sandy seagrass carpet.

96. PENHALE, P.A., "Primary Productivity, Dissolved Organic Carbon Excretion, and Nutrient Transport in an Epiphyte-Eelgrass (*Zostera marina*) System," Ph.D. Dissertation, North Carolina State University, Raleigh, N.C., 1977.

The biomass, productivity (^{14}C), and photosynthetic response to light and temperature of eelgrass (*Zostera marina*) and its epiphytes were measured in a shallow estuarine system near Beaufort, North Carolina, during 1974. The peak of the biomass (aboveground) was measured in March. Eelgrass and epiphyte productivity was low during the spring and early summer, peaked during late summer and fall, and declined during the winter.

The release and cycling of dissolved organic carbon by eelgrass and its epiphytic community were examined by measuring the excretion of dissolved organic carbon by eelgrass heavily colonized by epiphytes, the excretion by relatively uncolonized eelgrass, and the excretion by an epiphytic community attached to an artificial substrate. The excretion rates by eelgrass and epiphytes were low compared to total carbon fixation. The annual primary production and dissolved organic carbon excretion by phytoplankton, smooth cordgrass (*Spartina alterniflora*), eelgrass and its epiphytes were estimated. Eelgrass and its epiphytes contributed 47 percent of the total annual primary production and 14 percent of the total excreted material. Thus, the eelgrass and epiphytes play an important role in the primary productivity and the dissolved organic carbon cycles in this estuarine system.

97. PENHALE, P.A., and THAYER, G.W., "Uptake and Transfer of Carbon and Phosphorus by Eelgrass (*Zostera marina* L.) and its Epiphytes," *Journal of Experimental Marine Biology and Ecology*, Vol. 42, No. 2, Jan. 1980, pp. 113-123.

The uptake of carbon and phosphorus by eelgrass (*Zostera marina*) and its epiphytes under laboratory conditions was examined using ^{14}C and ^{32}P in partitioned chamber experiments. Both the carbon and phosphorus were taken up by eelgrass roots and subsequently transferred through the plants to epiphytes on the grass blades. The data suggested that only a small part of the carbon fixed in photosyntheses is supplied through the roots and rhizomes. There was very little net transfer of phosphorus through the plants during the 12-hour experiments; the most active movement of phosphorus was from the water into the roots where most of the material remained. Phosphorus uptake depended on the concentration of dissolved inorganic phosphorus in the medium. An increase in phosphorus concentration of the medium resulted in increased uptake rates; however, the proportion of accumulation of ^{32}P in the roots, leaves, and epiphytes remained similar. Experimental design should be carefully considered when comparing the results of various phosphorus uptake studies. The data indicated that a close relationship exists between eelgrass and its epiphytic community; 15 to 100 percent of the phosphorus released by the leaves was taken up by the epiphytes.

98. PHILLIPS, R.C., "Comprehensive Bibliography of *Zostera marina*," Special Scientific Report, Wildlife No. 79, U.S. Fish and Wildlife Service, Bureau of Sport Fish Wildlife, Washington, D.C., Jan. 1964.

This is an alphabetical listing by author of worldwide research on eelgrass (*Zostera marina*) prior to 1964. Abstracts are not included.

99. PHILLIPS, R.C., "On Species of the Seagrass Halodule in Florida," *Bulletin of Marine Science*, Vol. 17, No. 3, Sept. 1967, pp. 672-676.

Three vegetative leaf characters (leaf width, apex morphlogy, and the presence or absence of lacunae around the midvein), previously used to separate species of the seagrass Halodule, are shown to vary on the same plant, and also on plants in different environments, to such a degree that they cannot be used as species characters. Phillips' opinion is that all Halodule plants he observed from Florida waters belong to *Halodule wrightii* Ascherson.

100. PHILLIPS, R.C., "Ecological Life History of *Zostera marina* L. (Eelgrass) in Puget Sound, Washington," Ph.D. Dissertation, University of Washington, Seattle, Wash., Aug. 1972.

This report includes observations and experiments on the occurrence as well as vegetative and reproductive behavior of eelgrass in Puget Sound. Eelgrass was found from Admiralty Head on Whidbey Island, on both sides of Puget Sound, to east of a line from the Nisqually Flats to Henderson Bay in southern Puget Sound. Eelgrass was absent west of this line, and on the east side of Whidbey Island growth was patchy. Eelgrass in the Puget Sound is limited in depth to -6.8 meters. Transplants placed at -8.0, -9.6, and -10.6 meters indicated that vegetative growth at depths greater than -6.6 meters was favorable.

Intertidal turions were three to four times denser than subtidal turions, but maintained an average biomass approximately equal to that of subtidal turions. Rhizome biomass exceeded leaf biomass in fall, winter, and spring. Minimum vegetative biomass was found in winter; maximum biomass was found in summer. Vegetative activities of root and leaf growth were initiated in February, following a 2- or 3-month period of relative growth dormancy. The stimulus for vegetative and floral initiation in late winter is a photoperiodic response. Reproductive biomass was greatest from May through August. The maximum vegetative biomass occurred after the initial appearance of maximum reproductive biomass. By early August fruits began maturing and in late August and in September seeds were formed.

Seed germination occurred throughout the year, but predominantly from April to July, following the summer of their formation. Only those seeds which germinated from March to July attained sufficient growth to survive the erosive effect of fall storms. Only 1 to 6 percent of the seed crop germinated in normal strength seawater (30 parts per thousand), while up to 70 percent of the seeds germinated in dilute salinities. An eelgrass meadow was maintained by seed germination and vegetative growth. The latter method was the more significant. Geographic dispersal was by seed dissemination from floating reproductive turions.

101. PHILLIPS, R.C., "Temperate Grass Flats," *Coastal Ecological Systems of the United States*, B.J. Copeland, E.A. McMahan, and H.J. Odum, eds., Conservation Foundation, Washington, D.C., Vol. 2, June 1974, pp. 244-299.

Five species of seagrasses are reported from temperate North America. *Zostera marina* is the most important species with *Halodule wrightii, Phyllospadix sconleri, P. torreyi,* and *Ruppia maritima* of less importance. The distribution and ecology of eelgrass in the temperate zone of the world are discussed.

102. PHILLIPS, R.C., "Transplantation of Seagrasses, with Special Emphasis on Eelgrass, *Zostera marina* L.," *Aquaculture*, Vol. 4, Oct. 1974, pp. 161-176.

The history of transplanting seagrasses is given. Seagrass field planting methods are needed due to the extremely high productivity of seagrasses and the perturbations they are subject to. Data from experimental plantings indicate (a) distinctions in varieties based on leaf dimensions are invalid, (b) the possibility of local physiological race distinction, (c) the depth limit of eelgrass is due to a lack of suitable light deeper than a certain minimum depth, and (d) eelgrass seedlings require a higher light intensity than is present deeper than a certain minimum depth. Transplanting experiments provided much more information concerning seagrass biology than just planting method information.

103. PHILLIPS, R.C., "Seagrass, Food in the Inshore Coast," *Pacific Search*, Vol. 9, No. 9, Sept. 1975, pp. 2-4.

This is a study of seagrass as food for marine life. Seagrass at one time was not considered important to marine life, but it is now recognized as important not only to marine life but also to man. Seagrass is adversely affected by sewage. This project studied the annual growth and development cycle of eelgrass to develop planting methods for any season, and to develop new eelgrasses and turtlegrasses that are more adapted to man-influenced environment.

104. PHILLIPS, R.C., "Preliminary Observations on Transplanting and a Phenological Index of Seagrasses," *Aquatic Botany*, Vol. 2, No. 2, June 1976, pp. 93-101.

Transplanting of seagrasses yields basic biological information on tolerances to changes and extremes of water temperature and salinity, substrate, and chemical pollutants. Reciprocal transplants across tidal zones or across latitudinal distances can be used to distinguish whether responses represent phenotypic plasticity or ecotypic differentiation. Transplanting also represents the ability to maintain, create, or re-create seagrass meadows where human activity is increasing. It is important to know the phenology of seagrasses used in transplanting. A preliminary phenological index is given.

105. PHILLIPS, R.C., "Seagrasses and the Coastal Marine Environment," *Oceanus*, Vol. 21, No. 3, 1978, pp. 30-40.

Seagrasses create a diversity of habitats and substrates, providing a structured habitat from a structureless one. Because of their structure and physiology, seagrasses perform a wide assortment of biological and physical

functions in the coastal environment. They tolerate a wide range of salinities and water temperatures. The most important role of seagrasses in the food chain is their formation of detrius. There is an important relationship between seagrass detrius and nutrient cycling within and across ecosystem boundaries. Seagrass leaves act as a baffle that increases the rate of particulate sedimentation, preferentially concentrating the finer particles and stabilizing the underlying sedimentary deposits. Despite the ability of seagrasses to adapt to a fluctuating environment, several human-related activities threaten the hardy plants.

106. PHILLIPS, R.C., "Planting Guidelines for Seagrasses," CETA 80-2, U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Va., Feb. 1980.

An intensive review was made of the historical and present work on transplanting seagrasses, including eelgrass, turtlegrass, shoalgrass, manateegrass, and ditchgrass. The best seasons, recommended methods of transplanting, and propagules to use for each species are listed for the coasts of the United States. Some of the more important environmental parameters which directly influence successful transplanting are reviewed.

107. PHILLIPS, R.C., and McROY, C.P., eds., *Handbook of Seagrass Biology: An Ecosystem Perspective*, 1st ed., Garland, New York, 1980.

This book includes discussions of leaf morphology, anatomy, phenology, taxonomy, transplanting methods, culture methods, remote sensing of seagrass beds, productivity, faunal relationships, and detritus-decomposition relationships of seagrasses.

108. PHILLIPS, R.C., and SHAW, R.R., "*Zostera noltii* Hornem, in Washington, U.S.A.," *Syesis*, Vol. 9, 1976, pp. 355-358.

Evidence is presented to substantiate the use of the specific epithet *Zostera noltii* for a second species of Zostera in Washington State. The authors conclude that these plants do not constitute a new species, i.e., *Z. americana*.

109. PHILLIPS, R.C., VINCENT, M.K., and HUFFMAN, R.T., "Habitat Development Field Investigation, Port St. Joe Seagrasses Demonstration Site, Port St. Joe, Florida," Report No. TR D-78-33, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Miss., July 1978.

Shoalgrass (*Halodule wrightii*) was transplanted at Port St. Joe, Florida, using the plug technique. Two sizes of plugs were removed from a natural meadow and planted on coarse-grained, dredged material at three different spacings. Many of the transplants grew significantly before the project failed nearly 13 months after planting. Best growth was obtained with 375-square centimeter plugs planted on 0.9-meter centers. The reason for the project failure is not known.

110. PHILLIPS, R.C., et al., "*Halodule wrightii* Ascherson in the Gulf of Mexico," *Contributions in Marine Science*, Vol. 18, Sept. 1974, pp. 257-261.

An abundance of flowering material and fruiting material of Halodule was found in Redfish Bay, near Port Aransas, Texas, in May and July 1974. The

flowers agreed with the description of flowers given for *H. wrightii* in den Hartog (1970) and since leaf tip morphology varied from bidenate to tridentate in clonal material, it is concluded that this material is *H. wrightii*. It is also possible that all Halodule in the Gulf of Mexico is *H. wrightii*. The authors question the practice of creating new species in the genus Halodule based solely on whether vegetative leaf tips are bidentate or tridentate.

111. RANWELL, D.S., et al., "*Zostera* Transplants in Norfolk and Suffolk, Great Britain," *Aquaculture*, Vol. 4, No. 2, Oct. 1974, pp. 185-198.

Zostera noltii and *Zostera marina* var. *angustifolia* turfs have been transplanted on sheltered estuarine mudflats in carefully selected areas in Norfolk and Suffolk, Great Britain. Transplanting with turfs can be done on suitable mudflats where mud surface changes in level of at least +7 or +3 centimeters per week occur. Growth is favored in areas where a close balance between erosion and accretion occurs. Field scale transplanting of *Z. noltii* appears feasible in areas approaching 1 hectare in size at a cost of about $1,000 per hectare (1973 prices).

112. RINER, M., "A Study on Methods, Techniques, and Growth Characteristics for Transplanted Portions of Eelgrass (*Zostera marina*)," M.S. Thesis, Adelphi University, Garden City, New York, 1976.

Comparison was made of three transplant techniques for eelgrass (*Zostera marina*). More than 2,000 plug parts was planted. Survival was technique-dependent and varied from 100 percent for plugs to 36 percent for individual shoots, after 2 months. Miniplugs (survival rate of 71 percent) were best because of ease in harvesting, transporting, and planting. Large initial transport size resulted in greater production of material per unit time. Treatment of single shoots with the hormone, naphthalene acetic acid, was not advantageous. The use of a slow-release fertilizer resulted in greater dry weight values for the shoot and rhizome material. Transplants also showed a difference in growth response once removed from the established community. Transplant success can be achieved without anchoring devices. Areas with shifting sediments and current velocities approaching 1 knot prevent survival beyond 4 months.

113. ROESSLER, M., "Environmental Changes Associated with a Florida Power Plant," *Marine Pollution Bulletin*, Vol. 2, No. 6, June 1971, pp. 87-90.

Damage to the biota of Biscayne Bay by the heated effluent of a power-plant is demonstrated. Algae and seagrasses were replaced by blue-green filamentous algal mats; seasonal recovery was slow and the affected areas contained fewer kinds and smaller numbers of animals. Increased temperature was the chief cause.

114. ROGERS, R.G., "Seagrasses Revegetation in Escambia Bay, Florida," *Proceedings of the First Annual Conference on Restoration of Coastal Vegetation in Florida*, Hillsborough Community College Environmental Study Center, Tampa, Fla., May 1974, pp. 21-26.

Four species of seagrasses (*Vallisneria americana, Ruppia maritima, Halodule wrightii,* and *Thalassia testudinum*) were planted in three parts of Escambia Bay. The outcome of the project is not given. Future experimental trials of artificial seaweed are described.

115. SAND-JENSEN, K., "Biomass Net Production and Growth Dynamics in an Eelgrass (*Zostera marina* L.) Population in Vellerup Vig, Denmark," *Ophelia*, Vol. 14, Helsingaer, Denmark, Nov. 1975, pp. 185-201.

The biomass of an eelgrass population in Vellerup Vig, Denmark, showed a seasonal pattern, March to October 1974, with the peak in August. Biomass of leaves and flowering turions was quadrupled; biomass of rhizomes doubled from March to August. The maximum total biomass was 433 grams dry weight per square meter. The leaf population was determined by a leaf-marking technique, which also made it possible to estimate the rhizome population. From 9 April to 16 October 1974, the leaf production was 856 grams dry weight per square meter and the rhizome production 241 grams dry weight per square meter, which made a total of 1,097 grams dry weight per square meter. The dominance of leaf production, though leaf and rhizome biomass were of the same magnitude, resulted from a higher turnover rate of leaves (1.8 percent per day) than of rhizomes (0.7 percent per day). On the average a new leaf was produced on each turion every 14 days. The lifespan of the leaves was about 56 days. Total radiation and not temperature seemed to control leaf production. The maximum leaf production rate of 7.9 grams dry weight per square meter per day in mid-June coincided with maximum radiation. The total production was 3.8 times the net increase of total biomass and 2.5 times the maximum total biomass.

116. SCHUBEL, J.R., "Some Comments on Seagrasses and Sedimentary Processes," Special Report No. 33, John Hopkins University, Chesapeake Bay Institute, Baltimore, Md., Nov. 1973.

This report provides a brief review of some of the important relationships between seagrasses and sediments, and indicates a few of the problem areas where further research is needed.

117. SCOFFIN, T.P., "The Trapping and Binding of Subtidal Carbonate Sediments by Marine Vegetation in Bimini Lagoon, Bahamas," *Journal of Sediment Petrology*, Vol. 40, No. 1, Mar. 1970, pp. 249-273.

In the shallow-water lagoon of Bimini, Bahamas, the following plants are sufficiently abundant to influence sedimentation locally: red mangroves (*Rhizophora mangle*), turtlegrass (*Thalassia testudinum*), macroscopic green algae (*Penicillus, Batophora, Halimeda, Rhipocephalus,* and *Udotea*) and microscopic red, green and blue-green algae-forming surface mats of intertwining filaments (*Laurencia, Enteromorpha, Lyngbya,* and *Schizothrix*). Plants were observed under conditions of tidal currents and artificial unidirectional currents produced in an underwater flume, and measurements were made of the abilities of the plants to trap and bind the carbonate sediment. The density of plant growth is crucial in the reduction of current strength at the sediment-water interface. The most effective baffles are Rhizophora roots exposed above the sediment, dense Thalassia blades and Thalassia blades with dense epiphytic algae, *Laurencia intricata* and *Polysiphonia havanensis*. All three types can reduce the water velocity from a speed sufficiently high to transport loose sand grains along the bottom in clear areas (30 centimeters per second) to zero at the sediment-water interface in the vegetated areas. The strongest binders of sediment are the roots of Rhizophora and Thalassia. These two hardy plants trap and bind sediment for a sufficient time to produce an accumulation higher than in nearby areas without dense mangroves or grass. Macroscopic green algae growth is not sufficiently dense, and the holdfasts

are too weak to appreciably affect the accumulation of sediment although they provide a degree of stabilization to the substrate. Algal mats trap sediment chiefly by adhesion of grains to the sticky filaments. Their ability to resist erosion by unidirectional currents varies considerably depending on mat type, smoothness of surface and continuity of the cover. The intact areas of dense Enteromorpha mats can withstand currents five times stronger than those that erode loose unbound sand grains. Premature erosion of mats by currents occurs at breaks in the mat surface caused by the burrowing action of animals. Algal mats were found to be ephemeral features and consequently do not build up thick accumulations of sediment as do dense grass and mangroves. The thickest accumulation of sediment in the lagoon correlate with deepest bedrock surfaces. The distribution of many plants in the lagoon is directly and indirectly controlled by the depth to bedrock; e.g., red mangroves on high bedrock, turtlegrass in sediment-filled depressions.

118. SOMERS, G.F., ed., "Seed-Bearing Halophytes as Food Plants," Report No. DEL-SG-3-75, College of Marine Studies, University of Delaware, Newark, Del., June 1974.

The report discusses seed-bearing halophytes as food sources for man and domesticated animals. Contributions covered such subjects as domestication of wild rice, use of seagrasses and terrestrial halophytes as food plants, adaptation of present crops to saline habitats, and problems in managing saline soils.

119. STEVENSON, J.C., and CONFER, N.M., "Summary of Available Information of Chesapeake Bay Submerged Vegetation," Report No. FWS/OBS-78/66, Office of Biological Services, U.S. Fish and Wildlife Service, Washington, D.C., Aug. 1978.

Submerged aquatic species tend to inhabit the shallow, shoreline areas of the bay and its subestuaries, primarily limited to depths of 3 meters or less. Species vary as to salinity and temperature tolerance, morphology, preferred bottom substrate, susceptibility to chemical pollutants, and general distribution. There are approximately 11 species of submerged aquatic vegetation dominant in the waters of the Chesapeake Bay. Submerged aquatic flora constitutes the principal source of food for waterfowl and some fish; the flora provides direct and indirect food and shelter for many of the small host organisms that are eaten by fish and other predators. The spawning activities of certain organisms require submerged aquatic vegetation. The vegetation purifies the water by removing various noxious substances and returning oxygen, shades the underlying waters and sediments from solar heating, and provides an important source of detritus. Submerged aquatics help stabilize sediments and reduce shoreline erosion.

120. TAYLOR, J.L., SALOMAN, C.H., and PREST, K.W., Jr., "Harvest and Regrowth of Turtle Grass (*Thalassia testudinum*) in Tampa Bay, Florida," *Fisheries Bulletin*, Vol. 71, No. 1, Jan. 1973, pp. 145-148.

A comparison of leaf growth and new leaf production in plots of cut and uncut turtlegrass (*Thalassia testudinum*) indicated that plants suffered no damage when harvested twice during a 6-month season in Boca Ciega Bay (Tampa Bay), Florida. In deeper or warmer waters where the growing season is protracted, three or more cuttings per year may prove practical.

121. THAYER, G.W., and PHILLIPS, R.L., "Importance of Eelgrass Beds in Puget Sound," *Marine Fisheries Review*, Vol. 39, No. 11, Nov. 1977. pp. 18-22.

Eelgrass beds in Puget Sound, Washington, are important to many invertebrates. A partial list of invertebrates commonly collected in the Puget Sound beds and a list of commercial or recreational invertebrates and vertebrates are given. Invertebrates of the eelgrass beds are described as small epiphytes, attached fauna, motile users, and resting swimmers. The usefulness of the beds for food and shelter is discussed and related to the aquatic food chain.

122. THAYER, G.W., and STUART, H.H., "The Bay Scallop Makes Its Bed of Seagrass," *Marine Fisheries Review*, Vol. 36, No. 7, July 1974, pp. 27-30.

The bay scallop (*Argopecten irradians*), important commercially in eight Atlantic coast states, is more often associated with seagrass. In North Carolina one or more years of good scallop harvest have been followed by several years of poor harvest, the most recent being 1970-72. Commercial dredging and trawling for scallops and fish in shallow estuaries disrupt the vegetation and bottom, and this may impede the regrowth of the grass to which larval bay scallops attach. Commercial dredging significantly decreases both scallop and grass density, and it is suggested that annual or biannual rotation of scallop harvesting techniques might increase scallop productivity.

123. THAYER, G.W., ADAMS, S.M., and LaCROIX, M.W., "Structural and Functional Aspects of a Recently Established *Zostera marina* community, "*Estuarine Research*, Vol. 1, Academic Press, New York, 1975, pp. 518-540.

The value of eelgrass productivity to an ecosystem has been recognized for more than 50 years but little quantitative information is available. The epifaunal and infaunal invertebrates and the fishes inhabiting a grass bed in the Newport River estuary are dominated by only a few species. The density and biomass of these groups are greater than in the adjacent unvegetated areas. Fishes appeared to have some control over the density of the epifaunal community. The macrofauna consume an amount of energy equivalent to 55 percent of the net production of eelgrass, phytoplankton, and benthic algae in the bed. There is an excess of plant production in the bed, a part of which is increasing the organic content of the sediments. The remainder is exported. This export may be highly significant to the tropic function of the shallow estuarine system.

124. THAYER, G.W., ENGLE, D.W., and LaCROIX, M.W., "Seasonal Distribution of Changes in the Nutritive Quality of Living, Dead and Detrital Fractions of *Zostera marina*," *Journal of Experimental Marine Biology and Ecology*, Vol. 30, No. 2, Nov. 1977, pp. 109-127.

Samples of eelgrass (*Zostera marina*) were collected monthly from December 1974 to December 1975 in a shallow embayment near Beaufort, North Carolina, and separated into living leaves, dead leaves, and detritis. Each component was analyzed for dry weight, organic matter, inorganic and organic carbon, nitrogen and amino compounds.

The standing crop of living and dead leaves reached a maximum April through June. Detrital material peaked in December, April, and July to September. Inorganic carbon varied seasonally and represented 14, 24, and 30 percent of the total carbon associated with the living and dead leaves and

detrital fragments, respectively. Organic carbon was a decreasing proportion of the dry weight of the three fractions on a dry weight basis; there was a significant increase on an ash-free dry weight basis for the dead blades. During senescence there was a loss of nitrogen from the leaves and an increase in the nitrogen of the detritus relative to the dead leaves. The relative proportions of nitrogen-acetyl-glucosamine, nitrogen and organic carbon were all higher in the fall and winter.

125. THAYER, G.W., WOLFE, D.A., and WILLIAMS, R.B., "The Impact of Man on Seagrass Ecosystems," *American Scientist*, Vol. 63, 1975, pp. 288-296.

This report discusses seagrasses, especially Zostera and Thalassia and their distribution, environmental tolerances, and productivity. Coastal development, including dredging and pollution, can destroy seagrass beds by reducing light penetration, changing the redox potential of anerobic soils, or by adding toxins to the seagrass ecosystem. Other environmental disturbances are crude oil spillage, heated water discharge, and commercial fishing. The destruction of seagrass beds can have far-reaching impacts on organisms dependent on the grasses and detritus.

126. THOMAS, L.D., MOORE, D.R., and WORK, R.C., "Effects of the Hurricane Donna on the Turtle Grass Beds of Biscayne Bay, Florida," *Bulletin of Marine Science,* Vol. 11, No. 2, June 1961, pp. 191-197.

The dry and wet weight of *Thalassia testudinum* washed ashore at Biscayne Bay during Hurricane Donna in 1960 is estimated. Agents destructive to turtlegrass (other than wind) are discussed, and additional observations are included of hurricane damage to the turtlegrass beds of the Bahama banks.

127. THOMAS, M.L.H., and DUFFY, J.R., "Butoxyethanol Ester of 2, 4-D in the Control of Eelgrass (*Zostera marina* L.) and its Effects on Oysters (*Crassostrea virginica gmelin*) and other Benthos," *Proceedings of the Northeastern Weed Control Conference*, Vol. 22, 1968, pp. 168-194.

Eelgrass (*Zostera marina*) growth has a detrimental effect on oyster farming in eastern Canada. Results of preliminary experiments in chemical and mechanical control of eelgrass showed that mechanical control attempts by cutting or digging were short-lived, expensive, and frequently a failure. In earlier trials with various herbicides, only one was effective at reasonable concentrations without causing unacceptable mortalities of associated biota. This was a granular formulation of the butoxyethanol ester of 2N 4-D. Literature indicates that concentrations found in the field are not expected to harm animals.

128. THORHAUG, A., "Transplantation of the Seagrass *Thalassia testudinum* Konig," *Aquaculture*, Vol. 4, 1974, pp. 177-183.

The article covers gathering seed pods of turtlegrass, and preparing and planting the seeds. Laboratory seeding resulted in poor plant survival and near failure. However, field trials in Biscayne Bay, Florida, were successful with approximately 70-percent survival of seedlings 8 months after planting.

129. THORHAUG, A., "Transplantation Techniques for the Seagrass *Thalassia testudinum*," Sea Grant, Technical Bulletin No. 34, University of Miami, Miami, Fla., June 1976.

Turtlegrass (*Thalassia testudinum*) can be planted throughout the Gulf of Mexico, southeast Florida coast, and the Caribbean. Two planting methods,

seeding and plugging, are feasible, and the advantages of each are discussed. The seeding method appears to be most advantageous for dredged material stabilization. The plugging method is advantageous because plugs can be taken from mature beds throughout the U.S. coastal waters, whereas seeds are sparse or absent in many places. Plugging also may be done year round, while seeding is best in fall or spring.

130. THORHAUG, A., and AUSTIN, C.B., "Restoration of Seagrasses with Economic Analysis," *Environmental Conservation*, Vol. 3, No. 4, 1976, pp. 259-267.

Planting of seagrasses by use of plugs, turfs (sods), turions (shoots), and seeds is briefly described from a review of some pertinent world literature. The economic analysis evidently applies only to the cost of seeding Thalassia. Seeding densities to yield good cover in 2.5 years cost approximately $25,000 per 10,000 meters. If the same amount of cover is to be obtained in 0.8 year the cost will be three to five times greater.

131. THORHAUG, A., and HIXON, R., "Revegetation of *Thalassia testudinum* in a Multiple-Stressed Estuary, North Biscayne Bay, Florida," *Proceedings of the Second Annual Conference on Restoration of Coastal Vegetation in Florida*, Hillsborough Community College Environmental Study Center, Tampa, Fla., May 1975, pp. 12-27.

Plantings of *Thalassia testudinum* were made in the multiple-stressed estuary of North Biscayne Bay, Florida. Seeds were gathered by divers and tested in the varying condition of light, temperature, and flowing seawater. Seeds and seedlings were planted at eight field sites. The survival rate, growth, rhizome frequency, and planting techniques are discussed.

132. THORHAUG, A., BEARDSLEY, G., and HIXON, R., "Large Scale Transplantation of Thalassia in South Florida," *Proceedings of the First Annual Conference on Restoration of Coastal Vegetation in Florida*, Hillsborough Community College Environmental Study Center, Tampa, Fla., May 1974, pp. 18-21.

The marine grass *Thalassia testudinum* has been transplanted by sprigs on a small scale by several investigators in Florida. Sprig planting is time-consuming and has limited value. Only rarely does a plant without the apical meristem produce a new short shoot and thus grow laterally. The alternative of seed planting had not been tested until this experiment.

Fruit was collected manually by scuba divers. Seeds were dehisced by mechanical shock of freshweater and immediately cleaned and separated from fruit pod. Seedlings were rapidly transported to the planting area in aerated running seawater. Various concentrations and the soak time of napthalene acetic acid were tested. Seedlings were kept agitated in seawater until planted. Two 150-meter transects were established at Turkey Point, Biscayne Bay, Florida. These transects included three major zones of regrowth: *Halodule wrightii*, green siphonaceous algae, and bare peat. Part of the plants were anchored with plastic anchors, and part were without anchors. Planting was at 0.5, 0.25, and 0.1 meter in a pattern repeated every 50 meters. Approximately 15,000 seedlings was planted. Growth was vigorous. Mean growth of blades after 8 months was 16.5 centimeters. Approximately 80 percent of the plants remained in position; 10 percent washed out and were found in the immediate area of transplanting.

133. VanBREEDVELD, J.F., "Transplanting of Seagrasses with Emphasis on the Importance of Substrate," Florida Marine Research Publication No. 17, Florida Department of Natural Resources, Marine Research Laboratory, St. Petersburg, Fla., Nov. 1975.

Seagrass transplant experiments have emphasized the use of anchoring devices rather than the suitability of substrate. Thalassia needs an anaerobic environment, Halodule an aerobic substrate; Syringodium can thrive in either substrate. Transplants should be clumps of four to seven shoots with a few intact rhizomes. The original substrate is transferred with the plants. Plantings should be close together thus, offering the roots and rhizomes a favorable environment from the beginning and allowing them gradually to stabilize the surrounding area. Additionally, at least three rows should be planted for increased protection and transplant success.

134. WAYNE, C.T., "Sea and Marsh-Grasses: Their Effect on Wave Energy and Near-Shore Sand Transport," M.S. Thesis, Florida State University, College of Arts and Sciences, Tallahassee, Fla., Sept. 1975.

Sea and marsh grasses were found to reduce wave heights by as much as 71 percent and wave energy by 92 percent. Binding and trapping of sediments by the grass may modify the pattern of deposition. The effect of artificial seagrass on wave energy and near sediment transport was explored. The placement of offshore, artificial seagrass beds may influence nearshore sand transport. Artificial seagrass may decrease wave energy due to bending of the fronds, increased bottom drag, internal deformation and refraction.

A dense bed of seagrass can reduce total wave power and modify the wave approach angle. Through an adjustment of total wave power or β angle, alteration of the littoral component of wave power may be achieved with a corresponding reduction of erosion rates.

135. WELDON, L.W., BLACKBURN, R.D., and HARRISON, D.S., *Common Aquatic Weeds*, Dover Publications, Inc., New York, 1973.

This handbook was compiled to serve as a basis for the identification of the more common aquatic plants including widgeongrass and Vallisneria. The various plants have been observed, photographed, and, where necessary illustrated to show the more distinguishable characteristics. Each plant and its natural habitat, distribution, and importance are discussed.

136. WOOD, E.J.F., ODUM, W.E., and ZIEMAN, J.C., "Influence of Seagrasses on the Productivity of Coastal Lagoons," *Proceedings of Memorial Symposium International on Coastal Lagoons*, Institute De Biologica, Universidad Nacional, Autonoma de Mexico, Nov. 1967, pp. 495-502.

Seagrasses in coastal lagoons function to control or modify the ecosystem in the following ways:

(a) Serve as food for a very limited number of organisms such as the parrotfish, surgeonfish, Australian garfish, the Queen conch, sea urchins, and some nudibranch. The green sea turtle formerly grazed heavily on the turtlegrass. It has been found, however, that certain urchins grind up the seagrasses but do not appear to digest them; this may apply to other animals which appear to graze on the grass.

(b) Serve as hosts for large numbers of epiphytes which are grazed extensively, for example, by the mullets. These epiphytes may be comparable in biomass with the seagrasses themselves.

(c) Provide large quantities of detrital material which serves as food for certain animal species and for microbes which in turn are used as food by larger animals.

(d) Provide organic matter to initiate reduction and an active sulfur cycle.

(e) Bind the sediments and prevent erosion. This also preserves the microbial flora of the sediment and the sediment-water interface.

(f) Collect organic and inorganic material by slowing down currents and stabilizing the sediments.

The seagrasses have a rapid rate of growth (up to 9 millimeters per day, average 2 to 4 millimeters per day) and produce between 2.2 and 10.0 grams of dry leaf per square meter per day.

137. YOUNG, D.K., and YOUNG, M.W., "Regulation of Species Densities of Seagrass-associated Macrobenthos: Evidence from Field Experiments in the Indian River Estuary, Florida," *Journal of Marine Research*, Vol. 36, No. 4, Nov. 1978, pp. 569-593.

Field experiments in the Indian River estuary, Florida, were initiated in the seagrass beds, *Halodule wrightii*, to test effects of (a) excluding predators by caging, (b) enclosing predators inside cages, (c) adding dense populations of suspension feeders, (d) providing organic enrichment, and (e) removing seagrass blades.

The 11 most abundant species were selected for statistical testing of responses to the experimental treatments. Analyses showed that macrobenthic species differed markedly in their responses to the various treatments over a period of 1 year. Several species increased in densities with organic enrichment; whereas, some species increased in densities as a result of protection by the predator exclusion cage. When seagrass blades were clipped, some species increased in densities while others had decreased densities. These variations in response did not consistently correspond to taxonomic groupings or feeding types.

138. ZIEMAN, J.C., "Origin of Circular Beds of *Thalassia* (Spermatophyta: Hydrocharitaceae) in South Biscayne Bay, Florida, and their Relationship to Mangrove Hammock," *Bulletin of Marine Science*, Vol. 22, No. 3, Sept. 1972, pp. 559-574.

Aerial photos of a mangrove shoreline and an adjacent estuarine area in southwestern Biscayne Bay, Florida, showed the presence of numerous circular to teardrop-shaped areas. The circular areas on shore are hammocks of mangroves and other tropical trees, and they are over depressions in the bedrock which are filled with mangrove peat. The circular areas in the estuary are beds of *Thalassia testudinum*. Thalassia beds are often surrounded by a white halo of worm and callianassid burrows. The effect of sediment depth on density and length of blades is shown.

139. ZIEMAN, J.C., "Quantitative and Dynamic Aspects of the Ecology of Turtle Grass, *Thalassia testudinum*," *Estuarine Research*, Vol. 1, Oct. 1973, pp. 541-562.

Seagrasses bordering the temperate and tropical coastlines are a valuable resource. Techniques were developed to measure the production and seasonal dynamics of *Thalassia testudinum*. Production of leaf material varied from 0.3 to 10.0 grams dry weight per square meter per day in south Florida. Mean values were 2.3 to 5.0 grams dry weight per square meter per day. Leaf growth rates averaged 2 to 5 millimeters per day; maximum values exceeded 10 millimeters per day. The rhizomes of Thalassia were found 5 to 25 centimeters in the sediment, and roots penetrated 4 to 5 meters. Leaves constituted 15 to 22 percent of the total plant biomass, and leaf standing crops were found from 30 to 650 grams weight per square meter, with average values of 126 and 280 grams weight per square meter in inshore and offshore waters, respectively. Leaf densities averaged 3,460 to 4,300 blades per square meter. Thalassia was found to have an optimum temperature near 30° Celsius and an optimum salinity near 30 parts per thousand. Standing crop varied by about 50 percent throughout the year. Thalassia produced about 6.8 crops of leaves per year. Few were directly grazed. The leaves decayed rapidly, losing 65 percent of their original weight in 7 weeks.

140. ZIEMAN, J.C., "Methods for the Study of the Growth and Production of Turtle Grass, *Thalassia testudinum* Konig," *Aquaculture*, Vol. 4, No. 2, Oct. 1974, pp. 139-143.

Measurement of the productivity of vascular hydrophytes by gas exchange methods is inaccurate due to the storage of gases within the leaves. A method was developed for the study of turtlegrass (*Thalassia testudinum*), which allows (a) the monitoring of the blade populations without disturbing the plant, and (b) the determination of leaf growth and net production of the blades, in addition to other biotic variables associated with the growth and development of the plant. The technique involves the marking of individual blades with a modified stapler, and the retrieval of the marked blades after a 2- to 3-week interval. The production measured is that which is readily available as a nutrient source to the consumers of the Thalassia community.

141. ZIEMAN, J.C., "Tropical Seagrass Ecosystems and Pollution," *Tropical Marine Pollution*, E.J.F. Wood and R.C. Johannes, eds., Elsevier Scientific Publishing Co., New York, 1975, pp. 63-74.

This article provides a general discussion of seagrasses, their value to the coastal ecosystem, and the effect that pollutants and stresses have on seagrass beds. Halodule, Syringodium, Cymodocea, and Halophila are discussed; *Thalassia testudinum* is emphasized as the species on which most information has been collected. The adverse effects of dredging and filling, sewage, changing temperature, and salinity on seagrasses are discussed.

142. ZIEMAN, J.C., "Seasonal Variation of Turtle Grass, *Thalassia testudinum* Konig, with Reference to Temperature and Salinity Effects," *Aquatic Botany*, Vol. 1, June 1975, pp. 107-124.

Although turtlegrass (*Thalassia testudinum*) is a tropical marine plant, studies show it undergoes seasonal fluctuations. Maximum values of productivity, standing crop, leaf length, blade density, and other biotic variables are reached in the warmer summer months. Thalassia has a temperature

optimum near 30° Celsius and a salinity optimum near 30 parts per thousand. Deviations of these environmental parameters from their optima depress the biotic viability of the plant. Minimum values for the measured variables were encountered during periods of seasonally low temperatures or high temperatures coupled with lowered salinity. Thalassia has a slow response to environmental stress due to the stored starch reserves in the extensive rhizome system.

143. ZIEMAN, J.C., "The Ecological Effects of Physical Damage from Motor Boats on Turtle Grass Beds in Southern Florida," *Aquatic Botany*, Vol. 2, No. 2, June 1976, pp. 127-139.

Observation has shown that beds of turtlegrass (*Thalassia testudinum*), although highly productive, do not recover rapidly following physical disturbance of the rhizome system. In shallow waters the most common form of rhizome disturbance (boat damage) is from motorboat propellers.

In turtlegrass beds which are otherwise thriving, tracks resulting from propellers have been observed to persist from 2 to 5 years. The proportion of fine sediment components is reduced in the sediments from the boat markings, and the pH and EH are reduced in comparison to the surrounding grass bed.

This type of damage is most likely to occur in the shallow passes between islands and keys, areas that are also the slowest to recover due to the rapid tidal currents present in the shallow passes.

144. ZIEMAN, J.C., BRIDGES, K.W., and McROY, C.P., "Seagrass Literature Survey," Technical Report D-78-4, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Miss., Jan. 1978.

An extensive review of the published and unpublished literature pertaining to seagrasses, up to mid-1977, was prepared. Broad scientific subject areas that relate to seagrasses, such as anatomy, ecology, morphology, taxonomy, and physiology, were considered together with more specific factors such as substrate selectivity, water quality, productivity, colonization, effect of physical energy (waves, tidal currents, sediment transport), propagation, and tolerance to disturbance. The bibliography has a keyword index and also includes two appendixes, an author index and a source index, in microfiche form.

145. ZIMMERMAN, M.C., and LIVINGSTON, R.J., "Effects of Kraft Mill Effluents on Benthic Macrophyte Assemblages in a Shallow Bay System, Apalachee Bay, North Florida, USA," *Marine Biology*, Vol. 34, No. 4, Mar. 1976, pp. 297-312.

This study determined the impact of kraft-papermill effluents on the offshore benthic macrophyte distribution in a shallow north Florida bay. A polluted river drainage system was compared to an unpolluted one. The affected area was characterized by elevated levels of color and turbidity. In polluted areas, red and brown algae were proportionately more abundant than chlorophytes and spermatophytes. Except for areas of acute impact, there was no significant difference in species diversity between polluted and unpolluted parts of the bay. The pattern of macrophyte species composition reflected various water quality parameters. It was postulated that the reduction of normal dominants, such as *Thalassia testudinum* and *Halimeda incrassata*, allowed colonization by opportunistic species. Nearshore coastal systems in Apalachee Bay thus were affected by gradients in water quality in addition to natural (seasonal) fluctuations in key physical and chemical parameters.

IV. KEYWORD INDEX

Keyword	Reference Number
Algae	23, 26, 51, 60, 61, 113, 117, 145
Bibliography	47, 54, 74, 98, 144
Blowouts	95
Boat damage	143
Control	81, 127
Cymodocea	30, 31, 37, 44, 48, 141
Decomposition	35, 40, 41, 42
Depth	55, 81 100, 119
Diplanthera	18, 27, 30, 36, 37, 67, 84, 85, 86
Distribution	6, 7, 31, 44, 45, 50, 54, 61, 69, 81, 82, 85, 89, 100, 101, 117, 124, 125
Dredging	6, 21, 29, 30, 84, 109, 141
Ecology	1, 2, 3, 15, 17, 20, 28, 34, 46, 59, 62, 63, 73, 80, 82, 83, 86, 88, 97, 101, 119, 123, 137, 141
Eelgrass	1, 2, 3, 4, 5, 6, 10, 12, 13, 16, 21, 22, 38, 40, 41, 42, 44, 47, 54, 55, 57, 59, 60, 62, 63, 64, 69, 70, 71, 72, 74, 75, 76, 82, 83, 88, 89, 90, 91, 92, 96, 97, 98, 100, 101, 102, 103, 106, 108, 111, 112, 115, 121, 123, 124, 127
Epiphytes	37, 40, 46, 51, 62, 63, 72, 96
Erosion	6, 30, 95, 117
Fertilization	92
Field guide (key)	8, 27, 44, 47, 49, 135
Fish	1, 2, 3, 19, 20, 34, 82
Food chain	1, 2, 3, 16, 18, 20, 23, 34, 40, 48, 62, 103, 105, 119, 121, 137
Fungi	79
Geographical Area	
Alaska	12, 69, 70, 71, 77
Bahamas	85, 117
California	10, 13, 55
Canada	41, 60, 127
Caribbean	46, 95, 129
Chesapeake Bay	7, 11, 65, 88, 89, 90, 91, 92, 93, 119
Denmark	115
Florida	15, 18, 19, 20, 24, 39, 51, 52, 56, 78, 79, 81, 83, 85, 86, 87, 99, 109, 113, 114, 120, 128, 134
Grèat Britain	111
Gulf of Mexico	26, 29, 30, 31, 32, 34, 35, 37, 39, 50, 52, 56, 61, 67, 109, 110, 129
Mexico	28, 59
Mississippi	29, 31, 32, 50, 61
New Jersey	38
New York	16, 54

Keyword	Reference Number
North Carolina	1, 2, 3, 78, 96, 122, 124
Pacific Coast	10, 13, 100, 108, 121, 125
Puerto Rico	85
Texas	23, 27, 34, 35, 37, 67, 68, 84, 85, 110
Virginia	6, 7, 11, 63, 65, 88, 90, 91, 92, 93, 119
Washington (Pacific Coast)	100, 108, 121, 125
West Indies	95
Halodule	19, 29, 31, 39, 44, 52, 58, 59, 68, 83, 99, 101, 109, 110 114, 133, 137, 141
Halophila	27, 31, 39, 43, 44, 58, 59, 68, 141
Hormone	56, 106
Hurricane	32, 126
Ice	70
Invertebrates	3, 18, 28, 34, 40, 42, 46, 82, 83, 88, 89, 122, 137
Lagoons	10, 28
Light	10, 25, 58, 68, 102, 106, 125
Macrofauna	15, 88, 137
Manateegrass	19, 30, 31, 39, 52, 58, 59, 67, 68, 76, 106
Milfoil	11
Myriophyllum	11
Nutrient cycling	31, 34, 35, 37, 40, 41, 42, 72, 75, 76, 78, 80, 92, 96, 97, 124
Osmoregulation	53
Oyster	127
Photosynthesis	10, 12, 23, 84, 96
Phyllospadix	25, 101
Physical disturbance	90, 91 143
Planting	
Cost	9, 13, 21, 130
Methods	4, 5, 9, 13, 16, 19, 21, 29, 30, 56, 57, 65, 102, 103, 104 106, 107, 109, 111, 112, 114, 128, 129, 130, 131, 132, 133
Pollution	80, 141, 145
Predation	18, 89
Productivity	1, 2, 3, 6, 7, 10, 11, 15, 19, 23, 25, 28, 31, 34, 35, 37, 41, 42, 46, 48, 52, 55, 66, 67, 71, 75, 76, 84, 86, 94, 96, 97, 103, 107, 115, 120, 123, 124, 125, 136, 139, 140, 142, 145
Remote sensing	24, 38, 91, 107, 138
Ruppia	6, 8, 14, 19, 27, 28, 33, 37, 39, 58, 66, 68, 85, 92, 101, 114
Salinity	12, 14, 25, 30, 53, 66, 67, 68, 104, 105, 106, 118, 139, 141, 142
Scallop	122
Sediments	21, 29, 35, 54, 57, 64, 93, 95, 116, 117, 119, 133, 134, 143
Seed	5, 87, 100, 128, 132

Kewyord	Reference Number
Shoalgrass	18, 19, 30, 31, 36, 39, 44, 52, 67, 106, 109, 114
Stabilize sediments	6, 30, 117, 119
Stress	11, 12, 14, 18, 59, 70, 80, 89, 90, 91, 95, 103, 113, 120, 125, 126, 131, 141, 143, 145
Syringodium	18, 19, 39, 44, 48, 52, 58, 59, 67, 68, 76, 95, 133
Taxonomy	7, 8, 27, 33, 39, 43, 44, 45, 47, 49, 50, 53, 61, 87, 99, 107, 108, 110, 135
Temperature	12, 25, 30, 68, 104, 105, 106, 113, 125, 141, 142
Thalassia	9, 15, 18, 19, 27, 30, 31, 36, 37, 39, 44, 46, 47, 51, 52, 53, 56, 58, 59, 68, 76, 78, 79, 80, 83, 84, 85, 86, 87, 94, 95, 106, 114, 117, 120, 125, 126, 128, 129, 130, 131, 132, 133, 138, 139, 140, 141, 142, 143, 145
Turtlegrass	9, 15, 18, 19, 27, 30, 31, 36, 37, 39, 44, 46, 47, 51, 52 53, 56, 58, 59, 68, 76, 78, 79, 80, 83, 84, 85, 86, 87, 94, 95, 106, 114, 117, 120, 125, 126, 128, 129, 130, 131, 132, 133, 138, 139, 140, 141, 142, 143, 145
Urchin	18
Vallisneria	114, 135
Value	6, 26, 48, 73, 103, 105, 116, 118, 119, 121, 122, 123, 125, 134, 141
Waves	134
Widgeongrass (ditchgrass)	6, 14, 19, 28, 33, 37, 39, 58, 66, 68, 92, 101, 106, 135
Zostera	1, 2, 3, 4, 5, 6, 10, 12, 16, 21, 22, 38, 40, 41, 42, 44, 47, 54, 55, 57, 59, 60, 62, 63, 64, 69, 70, 71, 72, 74, 75, 76, 82, 88, 89, 90, 91, 92, 96, 97, 98, 100, 101, 102, 103, 106, 107, 111, 112, 115, 121, 123, 124, 127

Knight, Daniel B.
An annotated bibliography of seagrasses with emphasis on planting and propagation techniques / by Daniel B. Knight, Paul L. Knutson, and Edward J. Pullen. -- Fort Belvoir, Va. : U.S. Coastal Engineering Research Center ; Springfield, Va. : available from National Technical Information Service, 1980.
[46] p. : ill. : 27 cm. -- (Miscellaneous report -- U.S. Coastal Engineering Research Center ; no. 80-7)
Cover title.
This bibliography includes abstracts on 145 historic and recently published research reports on seagrasses, with emphasis on Halodule, Ruppia, Thalassia and Zostera. The compilation of reports emphasizes planting and propagation techniques for seagrasses and important environmental parameters for successful transplanting.
1. Annotated bibliography. 2. Seagrasses. I. Title. II. Knutson, Paul L. II. Series: U.S. Coastal Engineering Research Center. Miscellaneous report no. 80-7.

TC203 .U581mr no. 80-7 627

Knight, Daniel B.
An annotated bibliography of seagrasses with emphasis on planting and propagation techniques / by Daniel B. Knight, Paul L. Knutson, and Edward J. Pullen. -- Fort Belvoir, Va. : U.S. Coastal Engineering Research Center ; Springfield, Va. : available from National Technical Information Service, 1980.
[46] p. : ill. : 27 cm. -- (Miscellaneous report -- U.S. Coastal Engineering Research Center ; no. 80-7)
Cover title.
This bibliography includes abstracts on 145 historic and recently published research reports on seagrasses, with emphasis on Halodule, Ruppia, Thalassia and Zostera. The compilation of reports emphasizes planting and propagation techniques for seagrasses and important environmental parameters for successful transplanting.
1. Annotated bibliography. 2. Seagrasses. I. Title. II. Knutson, Paul L. II. Series: U.S. Coastal Engineering Research Center. Miscellaneous report no. 80-7.

TC203 .U581mr no. 80-7 627

Knight, Daniel B.
An annotated bibliography of seagrasses with emphasis on planting and propagation techniques / by Daniel B. Knight, Paul L. Knutson, and Edward J. Pullen. -- Fort Belvoir, Va. : U.S. Coastal Engineering Research Center ; Springfield, Va. : available from National Technical Information Service, 1980.
[46] p. : ill. : 27 cm. -- (Miscellaneous report -- U.S. Coastal Engineering Research Center ; no. 80-7)
Cover title.
This bibliography includes abstracts on 145 historic and recently published research reports on seagrasses, with emphasis on Halodule, Ruppia, Thalassia and Zostera. The compilation of reports emphasizes planting and propagation techniques for seagrasses and important environmental parameters for successful transplanting.
1. Annotated bibliography. 2. Seagrasses. I. Title. II. Knutson, Paul L. II. Series: U.S. Coastal Engineering Research Center. Miscellaneous report no. 80-7.

TC203 .U581mr no. 80-7 627

Knight, Daniel B.
An annotated bibliography of seagrasses with emphasis on planting and propagation techniques / by Daniel B. Knight, Paul L. Knutson, and Edward J. Pullen. -- Fort Belvoir, Va. : U.S. Coastal Engineering Research Center ; Springfield, Va. : available from National Technical Information Service, 1980.
[46] p. : ill. : 27 cm. -- (Miscellaneous report -- U.S. Coastal Engineering Research Center ; no. 80-7)
Cover title.
This bibliography includes abstracts on 145 historic and recently published research reports on seagrasses, with emphasis on Halodule, Ruppia, Thalassia and Zostera. The compilation of reports emphasizes planting and propagation techniques for seagrasses and important environmental parameters for successful transplanting.
1. Annotated bibliography. 2. Seagrasses. I. Title. II. Knutson, Paul L. II. Series: U.S. Coastal Engineering Research Center. Miscellaneous report no. 80-7.

TC203 .U581mr no. 80-7 627